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American Journal of Science

MARCH 1950

STRUCTURE AND ORIGIN OF TWO WINDOWS EXPOSED ON THE NITTANY ARCH AT BIRMINGHAM, PENNSYLVANIA

HAROLD D. FOX

ABSTRACT. There are two windows located on the axis of the southern end of the Nittany arch of central Pennsylvania. The windows are named the Birmingham window and the Knarr window.

The formations exposed within the windows are overturned, and have been graben faulted. The thrust which bounds the greater part of these two windows is low angle only within the area of the windows, and terminates very rapidly southwest of the windows.

The present interpretation of the structure of the windows differs from former interpretations. It is believed that local synclinal folding and faulting were the major factors in the development of the present structure. This was later covered by a thrust of relatively small stratigraphic displacement.

INTRODUCTION

IN the area surrounding the town of Birmingham, Pennsylvania, and along the Birmingham fault, two unusual windows (fensters) are exposed. Birmingham is located within the Tyrone quadrangle of central Pennsylvania, two and one-half miles southeast of Tyrone.

The region mapped is twenty-four miles long and an average of three and one-half miles wide. The location of the area and the surrounding topographic quadrangles are shown in figure 1.

The first geological work in this region was undertaken in the summer of 1841 by Harvey B. Hall, an assistant geologist of the First Pennsylvania Survey. In the summary report of the first survey H. D. Rogers (1858, pp. 503-504) included a section along the Little Juniata River from Union Furnace northwest to the town of Birmingham. It was in this report that the presence of a fault at Birmingham was first noted.

In 1881 Franklin Platt (1881) published a report of the geology of Blair County, and in 1885 J. P. Lesley (1885) published a report on Huntingdon County. These reports represented the work of the Second Pennsylvania Survey. It was

the opinion of these men that there was no major faulting at Birmingham.

No further work was done until the first decade of the twentieth century when Charles Butts mapped the Tyrone quadrangle. He realized for the first time that the rocks exposed

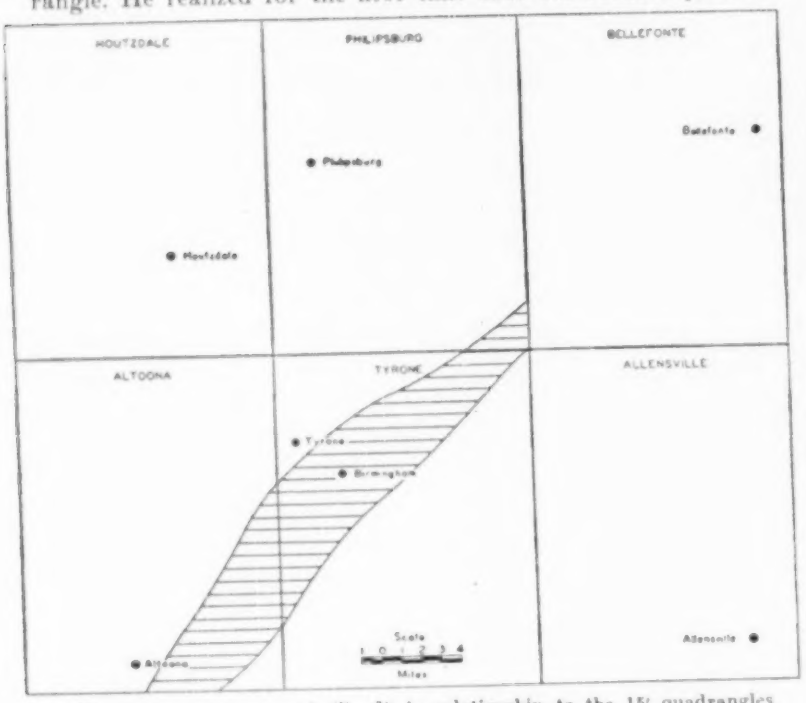


Figure 1. Area mapped (lined) in relationship to the 15′ quadrangles of central Pennsylvania.

at Birmingham were not of Cambrian age, but rather represented the Carlim- Tuscarora sequence of the upper Ordovician and lower Silurian. He (Butts, 1918) further noted that the beds at Birmingham were overturned.

It was not until Butts (1939) published his Tyrone quadrangle report that a second window, two miles northeast of Birmingham, was mentioned.

In the summer of 1947 the writer spent one week on reconnaissance of the general geology of the Birmingham region; and in the summer of 1948 eight weeks were spent in the field. Topographic maps were used as a base for mapping the area outside the two windows; but within the windows it was neces-

sary to use a base map of a larger scale. For detailed mapping, aerial photographs on scales of one to sixteen hundred and sixty-seven and one to one thousand were used.

It is interesting to note that no windows, except the two in the Birmingham area, have been reported in the northern section of the folded Appalachian province.

STRATIGRAPHY

The first detailed stratigraphic section of the formations mapped in the Tyrone quadrangle was published by Butts (1918). This was revised in his paper on the Tyrone quadrangle (1939). Later, G. M. Kay (1944) published the results of a detailed study of the middle Ordovician of central Pennsylvania. The detailed description of the formations of these groups will not be repeated here as it is covered in the papers mentioned above.

The Chazy and Black River are undistinguishable within the windows as these beds are brecciated to such an extent that only the gross lithologic relationships can be determined. It is possible to distinguish the Trenton from the Chazy and Black River, because the Trenton is darker and thinner. The basic difference between the two sections of Butts and Kay is the position of the boundary lines (Table 1), which was largely determined by the fauna. In working out the structure of the southern end of the Nittany arch these

TABLE 1

Comparison of published sections of Chazy, Black River, and Trenton stages.

Butts (1939)			Kay (1944)		
Formation	Thickness (in feet)	Stage	Formation	Thickness (in feet)	Stage
Reedsville	1100	Eden	Reedsville	——	Eden
			Antes	400	Trenton
Trenton	500	Trenton	Coburn	300	
			Salona	200	
Rodman	30	Black River	Nealmont	150	
Lowville	337		Curtin	140	Black River
			Benner	40-200	
Carlim	250	Chazy	Hatter	70-110	Chazy
			Loysburg	50-80	

differences are negligible. It was found expedient, therefore, to follow Butts' classification since his formation names are used on the only published areal geological map of the Tyrone quadrangle.

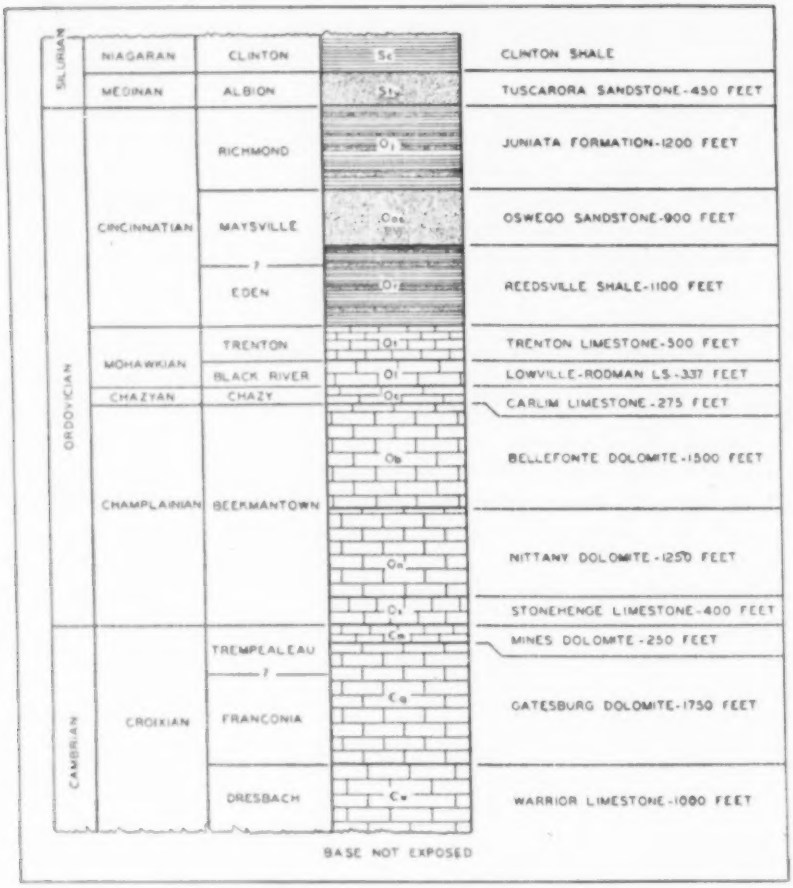


Figure 2. Stratigraphic section of rocks exposed on the south end of the Nittany arch (modified after Butts, 1938).

Figure 2 is a stratigraphic section of the formations as mapped in this paper.

STRUCTURE

The Nittany Arch. The last great westward structure of the folded Appalachians is the Nittany arch. To the north-

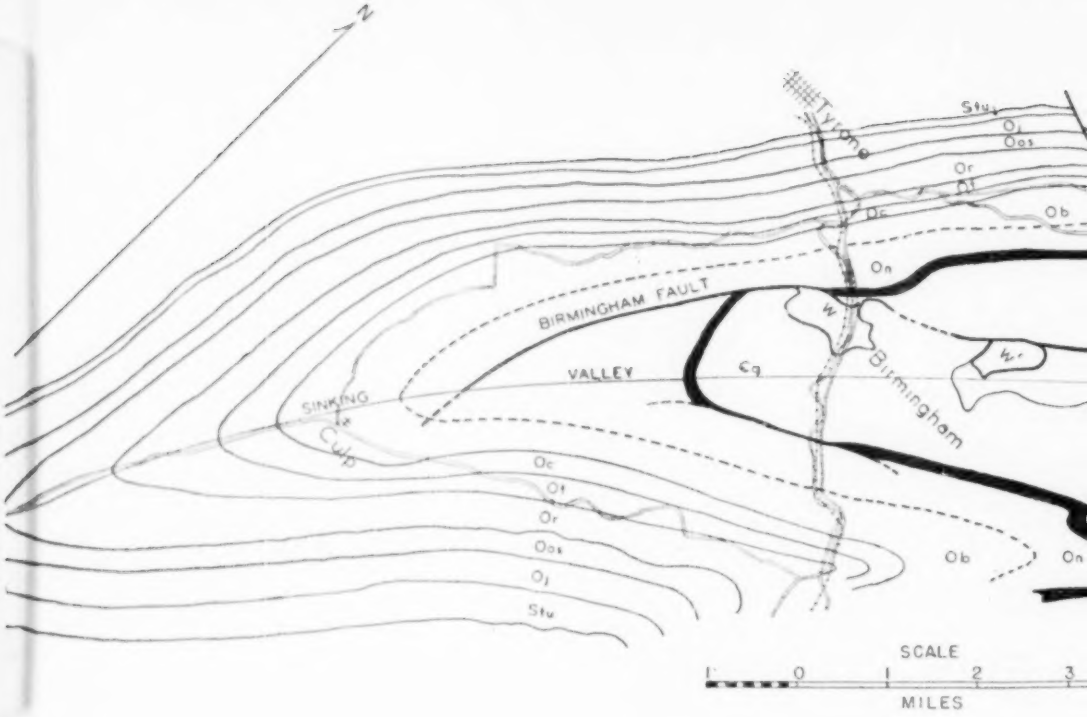
west are the minor folds of the Allegheny plateau; and southeastward the folded Appalachians extend for fifty-three miles to the Piedmont Province. This arch, which really is an anticlinorium, extends from Altoona to Muncy, ten miles east of Williamsport, a distance of 110 miles. Across the strike it reaches from the Allegheny escarpment, northwest of Tyrone, to the Broad Top syncline southeast of Huntingdon, thus having a minimum width of twenty-six miles.

The Nittany arch has a consistent northeast-southwest strike throughout its length. Where the arch dies out by plunging to the northeast, the trend of the Appalachian folding swings through a major change of some 40° to the east. The plunging to he northeast, the trend of the Appalachian folding the Sinking Valley anticline (fig. 3). The axis may be considered to extend from north of Warriorsmark to seven miles south of Altoona, a distance of more than twenty-five miles. This anticline is asymmetrical, dips on the southeast flank averaging 25° to 35°, whereas the beds on the northwest flank are at first overturned to the southeast, then vertical, and gradually flatten out to the northwest. Along the Allegheny escarpment the dips are 15° or less to the northwest.

The Birmingham Fault. The south end of the Nittany arch is broken by the Birmingham fault. This fault lies along the axis of the arch, extending from one mile northeast of Culp to four miles southwest of Bellefonte, a distance of some thirty miles. Figure 3 shows the southern nineteen miles of this fault.

From the vicinity of Warriorsmark northward it appears to be a fairly high angle fault. Although no dip was obtained in the field, the trace of the fault plane through irregular topography indicates that it dips 40° to 50° to the southeast. North of Warriorsmark, where the upper Warrior limestone is thrust against the Stonehenge, the stratigraphic throw is about 1800 feet. At Stormstown, more than eight miles farther northeast, where the upper Warrior is thrust against the lower Nittany dolomite, the stratigraphic throw is about 2000 feet.

In the vicinity of Birmingham the fault is folded, as shown by the windows, and the dip is much lower and variable. At Birmingham the fault is exposed along a railroad cut (pl. 1, fig. 1). The local dip at this exposure is 15° to the southeast.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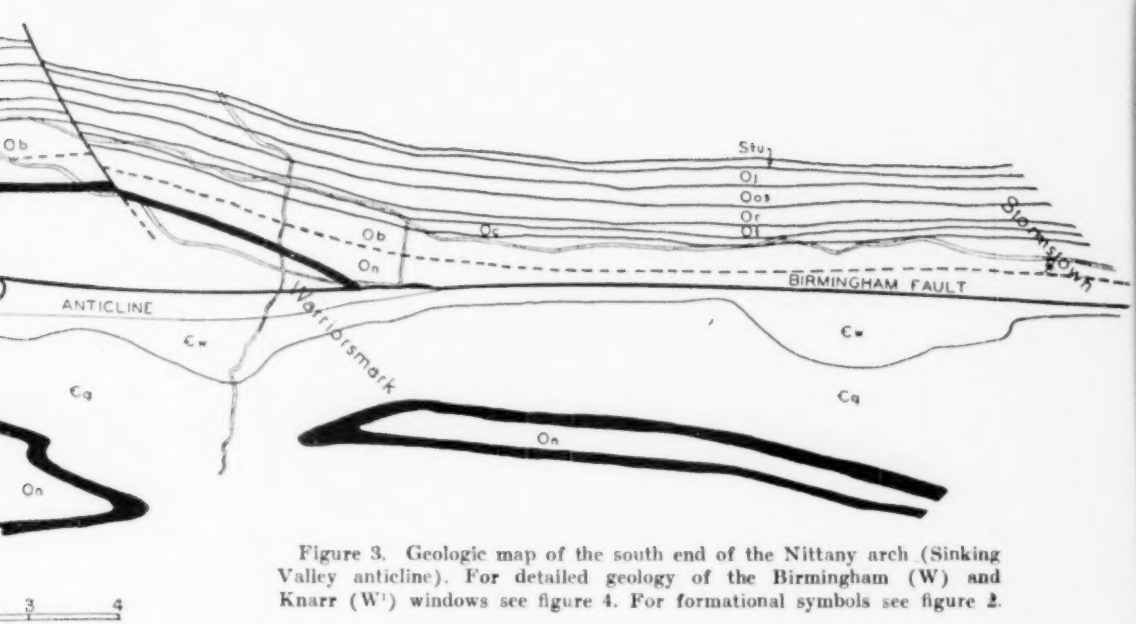

Figure 3. Geologic map of the south end of the Nittany arch (Sinking Valley anticline). For detailed geology of the Birmingham (W) and Knarr (W^1) windows see figure 4. For formational symbols see figure 2.

Figure 4. Detailed geologic map of Birmingham and K
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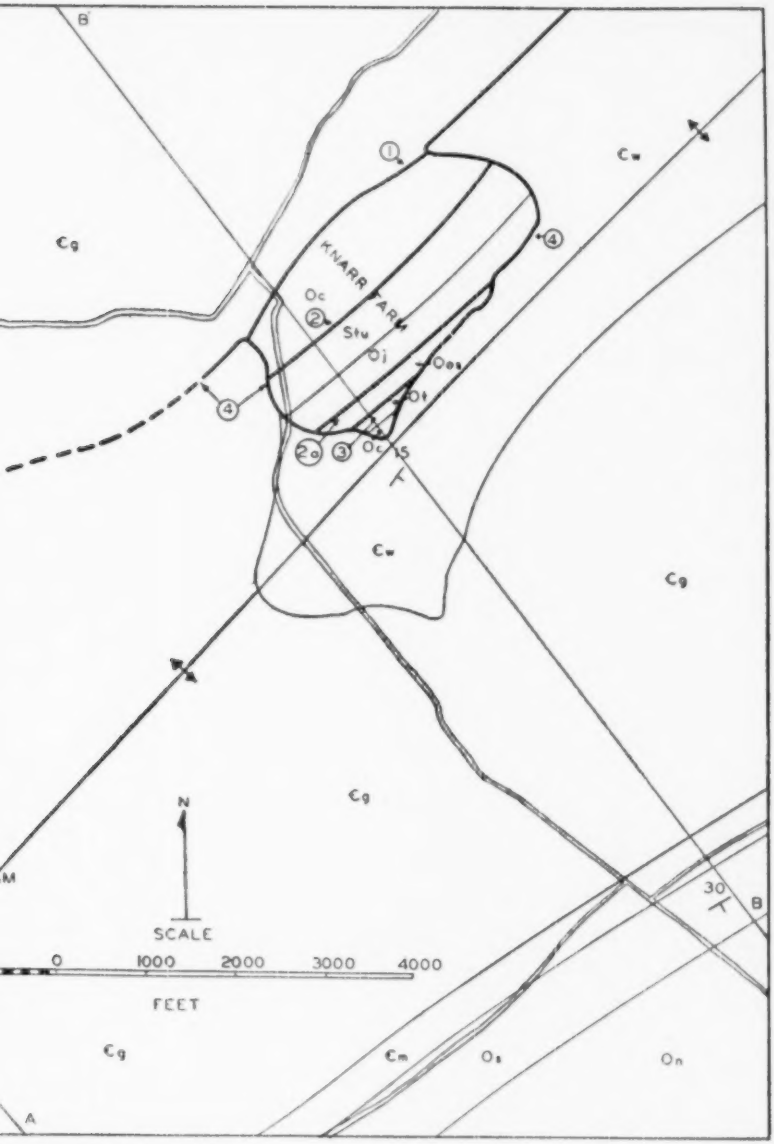


d Knarr windows. Circled numbers indicate individual faults.
al symbols see figure 2

The fault here forms the southeast frame of the Birmingham window, and the stratigraphic throw is a minimum of 5000 feet. One and one-half miles southwest of Birmingham the Stonehenge is thrust over the lower Nittany, and the stratigraphic throw is less than 1000 feet. Beyond this point the throw decreases rapidly, and five miles south of Birmingham the fault is no longer evident.

The Birmingham Window. Along the top of the Nittany arch, an area of overturned formations at Birmingham was described by Butts (1939), and it is here named the Birmingham window. This window is about one mile long and half a mile wide (fig. 4). It is surrounded by the Gatesburg dolomite except for about 2000 feet along the northwest edge, where the Stonehenge limestone and the Nittany dolomite form the boundary.

A section along the main highway from southeast to northwest begins just southeast of the axis of the arch in the Gatesburg dolomite, which is dipping 10° to the southeast (fig. 5), section A-A^1, and fig. 4). Here the Birmingham fault (fault 4, figs. 4 and 5) has thrust the Gatesburg dolomite over the Carlim limestone, and forms the south frame of the window. The Carlim is then exposed for 1200 feet. Since it is impossible to distinguish between the Carlim, Lowville and Rodman, because of folding and shattering, all the massive limestone within the window is mapped as Carlim. The Carlim-Trenton contact appears to be normal, although the beds are upside down with the Carlim lying above the Trenton. The Trenton has been highly folded, and it is impossible to obtain a dip that has much significance throughout the 250 feet which it covers. At the most, only 125 feet of the original 500 feet of the Trenton is present. The contact between the Trenton and the Oswego sandstone is a fault contact. This fault (fault 3, figs. 4 and 5) has cut out the remaining Trenton, the Reedsville shale, and part of the Oswego: thus having a minimum stratigraphic throw of 1750 feet. There is 200 feet of Oswego sandstone exposed dipping about 45° to the southeast; thus only 140 feet of the normal thickness of 900 feet of the Oswego is present. The last twenty feet of Oswego is covered, but the contact between the Oswego and the Juniata formation must be assumed to be a fault (fault 2a, figs. 4 and 5) as the normal thickness of the Juniata is

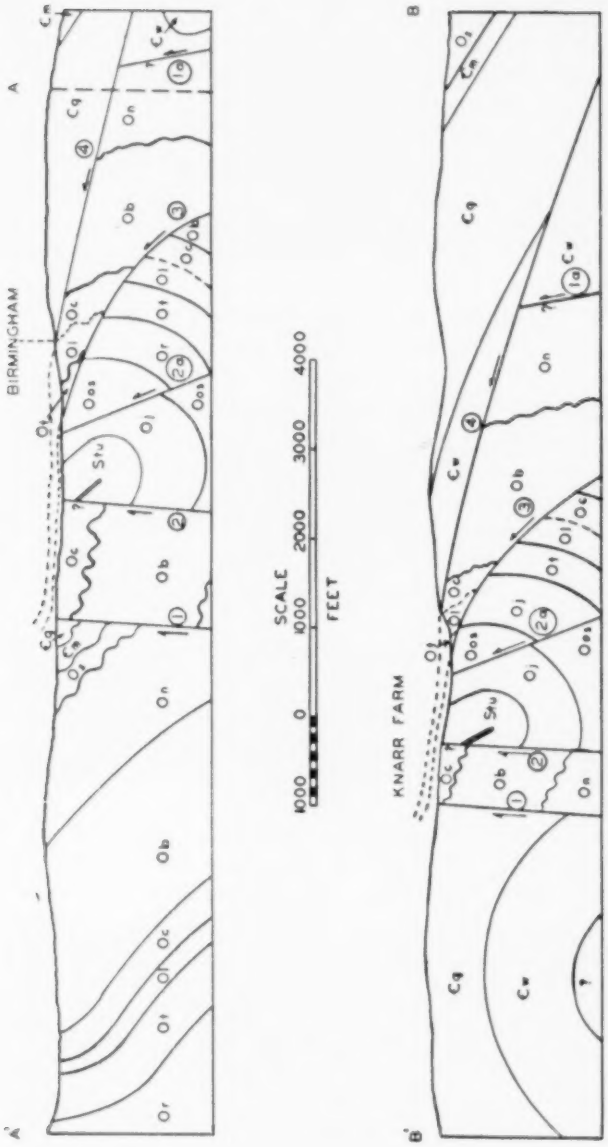


Figure 5. Geologic structure sections of Birmingham and Knarr windows, along lines A-A' and B-B' of figure 4. Faults numbered as in figure 4. For formational symbols see figure 2.

not present. There is 300 feet of Juniata exposed, and here the first significant dips may be taken. The Juniata dips 45° S. 40° E. Thus only 210 feet is left of the normal Juniata thickness of 1200 feet. The contact between the Juniata formation and the Tuscarora sandstone is gradational and normal. The Tuscarora dips 45° S. 40° E. The width of its outcrop is 480 feet, and, therefore, only 330 feet of the original 450 feet is exposed.

The window thus contains a sequence of overturned younger beds, all of which have been greatly reduced in thickness by shearing.

Bed rock is covered for the next 1200 feet by the flood plain of the Little Juniata River. This covered zone is terminated by outcrops of the Carlim limestone, just southeast of the Bald Eagle Water Co. pumping station. Here 50 feet of Carlim is exposed. The sequence of formations within the Knarr window, one mile to the northeast, indicates that this covered area may be underlain entirely by Carlim limestone, and it has been so mapped. If this is true the Tuscarora-Carlim contact is a fault (fault 2, figs. 4 and 5). This Carlim is the last formation within the window, and it is thrust against the upper Gatesburg.

Continuing northward along the highway, the Mines dolomite, Stonehenge limestone, and Nittany dolomite are all found in reverse sequence. The dips are to the southeast although, because of local folding, it is not possible to obtain a significant reading. The dip of the Nittany near the Nittany-Bellefonte contact is 35° S. 30° E. The Bellefonte is also overturned, and the reverse dip at about the center of the formation is 30° S. 45° E. From this point northwestward the beds slowly right themselves. The Carlim and Trenton still maintain a reversed position, the Trenton near the Reedsville contact dipping 75° S. 30° E. The Tuscarora beds are vertical at Tyrone.

Another important section through the Birmingham window is along the railroad cut of the Pennsylvania Railroad. This section is southwest of the river and roughly parallel to the main highway. Although the distance between these two sections averages only 300 feet, there is a surprising difference in the beds exposed.

The Birmingham fault appears along the railroad cut 1600

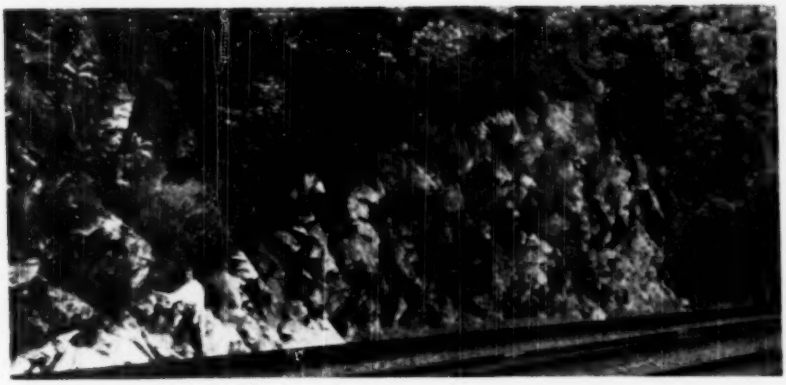


Plate 1, figure 1. Birmingham fault exposed along the main line of the Pennsylvania R. R. 1600 ft. south of Birmingham Station. The Gatesburg (dark colored) is thrust over the Carlim. View looking southwest.

Plate 1, figure 2. The Birmingham window (center) from Bald Eagle Mountain looking across the Nittany arch to the southeast.

Plate 1, Figure 3. The Knarr window looking north. The Warrior limestone forms the ridge in the foreground. The dashed line is the boundary of the window.

feet southeast of Birmingham Station (pl. 1, fig. 1). Here, the lower Gatesburg is thrust over the Carlim, and the local dip of the fault plane is 15° to the southeast. Along the railroad northwest from this fault exposure there is 2850 feet of Carlim limestone. It is impossible to obtain significant dips within this distance as the Carlim has been badly folded and smashed. This Carlim cuts across the strike of the Oswego-Juniata-Tuscarora sequence observed in the section along the highway. That is, the Oswego-Juniata-Tuscarora sequence does not cross the river since it has been cut off by fault 3.

A small amount of Trenton limestone, less than 200 feet, appears before fault 3 is reached. Since the Carlim here again overlies the Trenton, it would seem that all the Carlim is overturned. The rest of the section along the railroad corresponds to the section previously described along the highway.

The Birmingham fault (fault 4) and fault 3 are flat, low angle, southeasterly dipping thrusts and are closely related in origin. An altimeter survey of the outcrops of these two faults shows that they have been folded (fig. 6). In the northeast portion of the Birmingham fault (no. 4) between eleva-

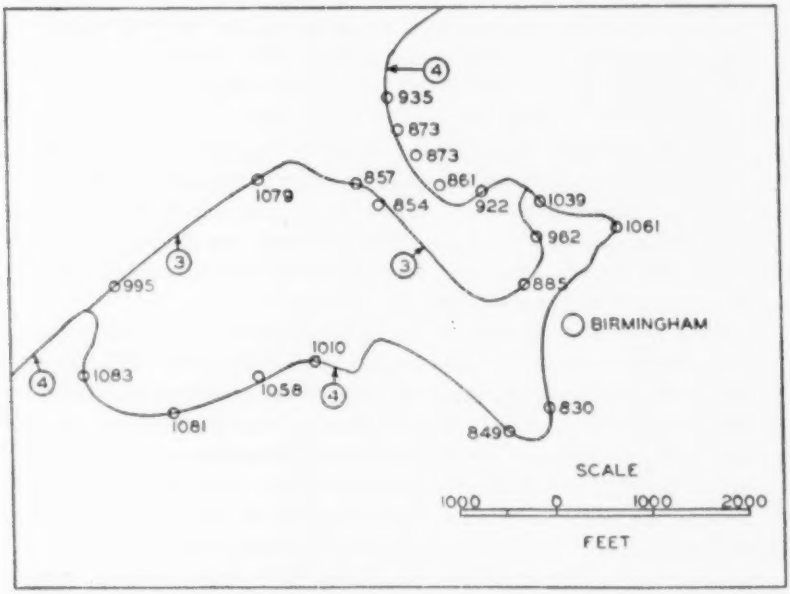


Figure 6. Elevations on the outcrops of faults 3 and 4 at Birmingham.

tions 1061 and 861 there is a reversal of the dip of the fault plane. The lower thrust (no. 3) has no complete reversal, but between elevations 855 and 857, a distance of 1900 feet, the dip of this fault is almost flat. However, between 857 and 1079, a distance of only 1100 feet, there is a marked southeast dip. Therefore, both of these thrusts have been warped by subsequent folding.

Fault 3, the lower of these thrusts, forms the greater portion of the northwestern border of the window. The rest of the window is bounded by fault 4, except for about 1000 feet bounded by fault 1. Actually the structure is a semi-window, rather than a true window, since no one fault completely surrounds it.

Faults 1, 2, and 2a are all high angle faults as shown by their outcrop patterns. Although there is no field evidence as to their direction of dip, they are thought to be high angle reverse faults.

The Knarr Window. A little over a mile northwest of Birmingham, along the axis of the Nittany arch, a smaller window is exposed. It covers an area 3800 feet long and 1900 feet wide. Since the Knarr farms lie near the center, it is here named the Knarr window (fig. 4 and pl. 1, fig. 3). The Gatesburg and Warrior formations enclose the window and the Birmingham fault (fault 4) bounds two-thirds of it. The northwest side is framed by fault 1.

The Knarr and Birmingham windows are very similar. The same sequence, and also about the same thicknesses, of formations are found in both windows. Moreover, all of the faults are present in both windows. The faults in the Knarr window are numbered the same as their counterparts in the Birmingham window (figs. 4 and 5).

Two apparent differences in the exposures of the two windows should be noted: fault 3 is exposed for only 1000 feet along the southeastern edge of the Knarr window; and much less Carlim is exposed in the Knarr window than in the Birmingham window. These apparent differences are thought to be the result of greater warping of the fault planes of the two low angle thrusts (no. 3 and no. 4) in the Birmingham window, together with a greater amount of erosion of that window. Actually, there are no basic differences between the two windows, and they are merely separate exposures of the

same fundamental structure. Therefore, where field evidence was missing in one window it was supplied from better exposures of the same sequence within the other window.

ORIGIN AND DEVELOPMENT OF THE STRUCTURE OF THE SOUTHERN END OF THE NITTANY ARCH

The Nittany arch is the westernmost fold of the northern Appalachians and is one of the largest structures of this province. To the west of this arch the beds of the Allegheny plateau are only slightly disturbed by folds of an entirely different nature. Price (1931) discussed the effect of a regional inherent weakness in the geosyncline as a controlling factor in the location and development of this arch. Even though it is over one hundred miles long and better than thirty miles wide, it is an overturned fold with some of the beds on the northwest flank dipping approximately the same direction and amount as those on the southeast flank. This fact places a large overturned syncline between the axis of the Nittany arch and the Allegheny escarpment to the west.

Along the crest of the Nittany arch is the Birmingham fault. This fault, except for the complicating factors exposed within the two windows, is a rather small thrust which has broken the arch at about its axis. At Stormstown (fig. 3) the stratigraphic throw of the Birmingham fault is about 2000 feet, and at Warriorsmark it is about 1800 feet. With the exception of the exposures within the windows, the throw decreases southwest of Warriorsmark until the fault disappears in Sinking Valley, along the plunge of the fold.

Within the two windows, the throw of the Birmingham fault suddenly increases to a maximum of some 8000 feet. However, as shown above, this fault is a relatively small thrust throughout the greater part of its length. Therefore, the problem is: Why does the Birmingham fault suddenly greatly increase its throw within the windows? The causes which brought this about should probably be local.

The extent of the structure within the windows may be related to two local peculiarities in this part of the Nittany arch. The first is the change of the Birmingham fault from a high angle to a low angle thrust in the area within and between the windows. The second is a bulge of the west flank of the Nittany arch to the northwest of about a mile. This departure

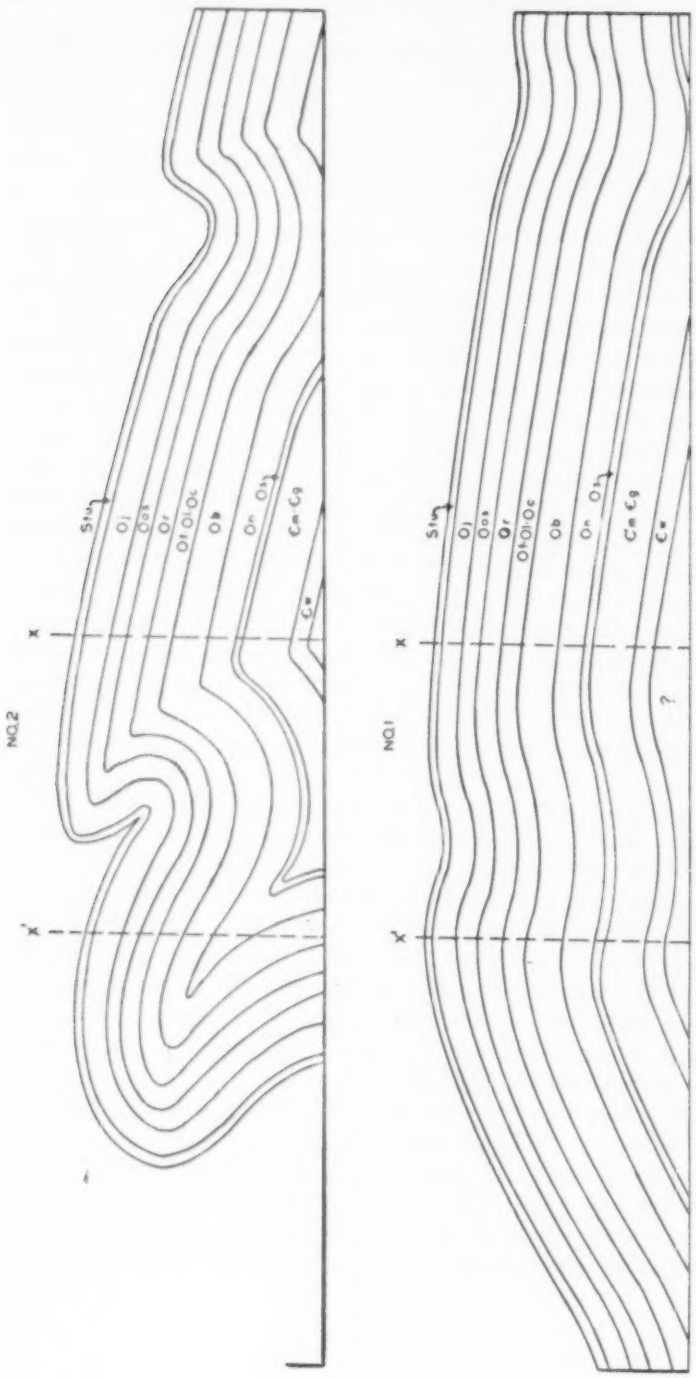


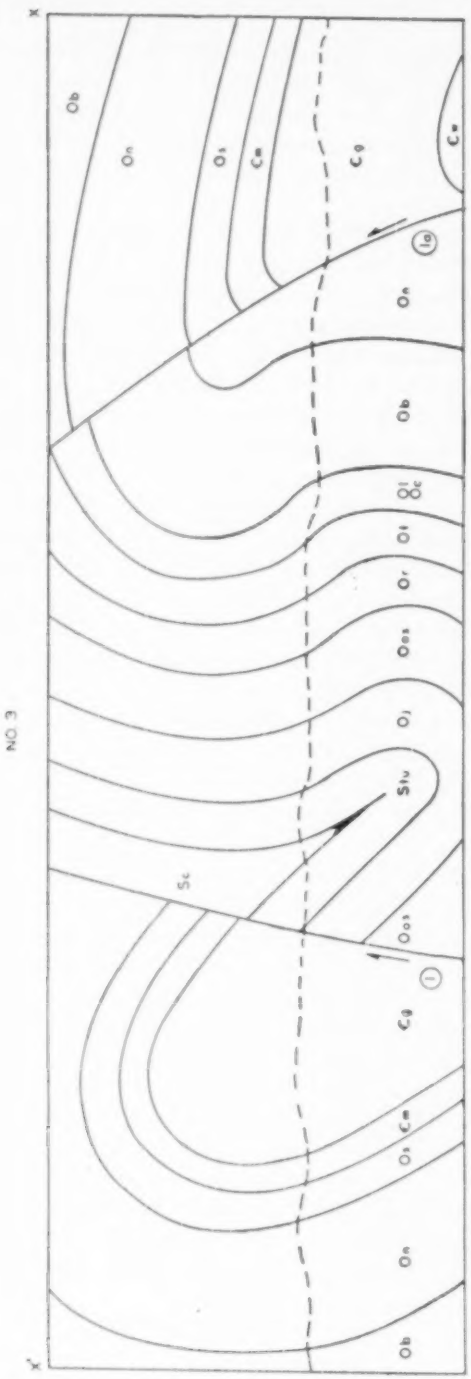
Figure 7. Schematic structure sections along line A-A', fig. 4, showing first two stages in the development of the Birmingham and Knarr windows. For formational symbols see figure 2.

from the usual trend is partly caused by the strike slip displacement along a small transverse fault (see fig. 2). The bulge is limited to that portion of the flank opposite the windows. It would seem, therefore, that the conditions which brought about the structure exposed within the windows are of a local nature.

Development of the Windows. It is suggested that early in the development of the Nittany arch a local syncline was formed near the crest of this large arch (fig. 7, no. 1). This small syncline was overturned before it was faulted (fig. 7, no. 2), and its southeast flank is the Oswego-Juniata-Tuscarora sequence within the windows. It should be noted that the degree of overturning is the same as that of the major syncline between the axis of the Nittany arch and the Allegheny escarpment (both dip 35° to 45° S. 35° to 45° E.). Since this small syncline disappears southwest of Birmingham, it must plunge to the northeast, which is counter to the plunge of the Nittany arch. The resulting torque should have sheared and weakened the flanks. They failed, and a fault trough was formed. The bounding faults are thought to be high angle reverse faults as the graben was developed under active compression (fig. 8, fault 1 and 1a). At about the same time a smaller graben was formed within the larger graben (fig. 9, no. 4, faults 2 and 2a). Although for clarity these grabens are shown as though they developed separately, it is thought that they formed at about the same time. The faulted syncline was later overridden by two low angle thrusts (fig. 9, no. 5, faults 3 and 4). Fault 3 forms the base of a lower plate and is the older. The Birmingham thrust (fault 4) is the youngest and completely overrode the entire sequence. The thrusts were then slightly folded, and subsequent erosion has exposed the windows and uncovered the underlying structure.

Within the area of the two windows the strong rocks, the Oswego and Tuscarora sandstones, caused the Birmingham thrust to ride up and then across at a low angle. Outside this area, however, where the local syncline and infolded sandstones are not present, the sheet rode up against less interference. The change in the character of the Birmingham fault from high to low angle is paralleled by the change in trend of the west flank of the Nittany arch previously mentioned.

In lower Sinking Valley the Carlim and the Trenton forma-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tions have been brecciated, jointed and veined, even though there is no displacement of the Carlim-Bellefonte contact. This fracturing reflects the final absorption of the major faulting present at Birmingham. Sphalerite and galena mineralization is scattered throughout lower Sinking Valley, and is also present in the fracture zones within the windows. This mineralization has been structurally controlled and reflects the effect of major faulting at depth.

Comparison of Present Interpretation with Previous Interpretations. In Butts' paper (1939) two separate interpretations are set forth. The first of these is Butts' own interpretation which includes both a discussion and a structure section (fig. 10, upper section), and the second an alternative interpretation by G. W. Stose (fig. 10, lower section). Stose's section is based upon field data furnished him by Butts. At the conclusion of his interpretation Butts (1939, p. 78) says, "no fully satisfactory explanation of the entire situation has as yet been reached."

It is difficult from the discussion in Butts' paper to determine how he thought the windows were developed. It would seem that the major differences between the origin here proposed and the suggestions of Butts and Stose are:

(a) The size and location of the syncline. Both Butts and Stose would seem to require a major syncline that has been thrust a considerable distance from where it was formed. This interpretation makes it difficult to explain the rapid termination of the faulting to the southwest.

(b) The role of the Birmingham thrust. Butts and Stose thought that this fault was very large. In Butts' interpretation this fault must have a throw of about three miles; and all the faults in Stose's section are integral parts of a low angle thrust of large displacement. Here again a fault of this nature is contrary to the field evidence of the Birmingham thrust outside the area of the windows.

It would seem that a local syncline, later block faulted, would more nearly explain the present position of the formations exposed within the windows. This structure was overridden by the Birmingham fault, which was caused by the compressive forces that formed the southern half of the Nittany arch.

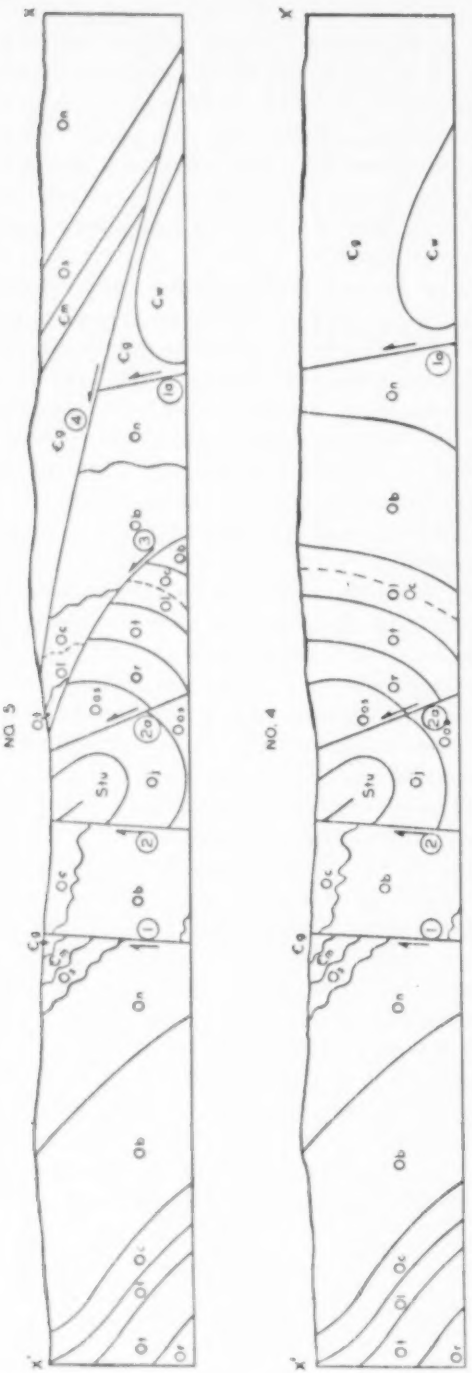

Figure 9. Schematic structure sections along line A-A', figure 4, showing last stages in the development of the Birmingham and Knarr windows. For formational symbols see figure 2.

Comparison with Windows Elsewhere in North America. Windows in major thrust sheets such as those in the Cumberland overthrust of Virginia (Butts, 1927), and the Bannock thrust sheet of Idaho (Richards and Mansfield, 1912) differ basically from the two windows here discussed. The windows of the Cumberland and Bannock thrusts are related to large low angle thrust sheets with displacements of tens of miles. However, the rocks exposed within the Birmingham and Knarr windows are not associated with such a large low angle thrust, and their present position is due to local synclinal folding and block faulting, later covered by a thrust which is low angle only within the area of the windows.

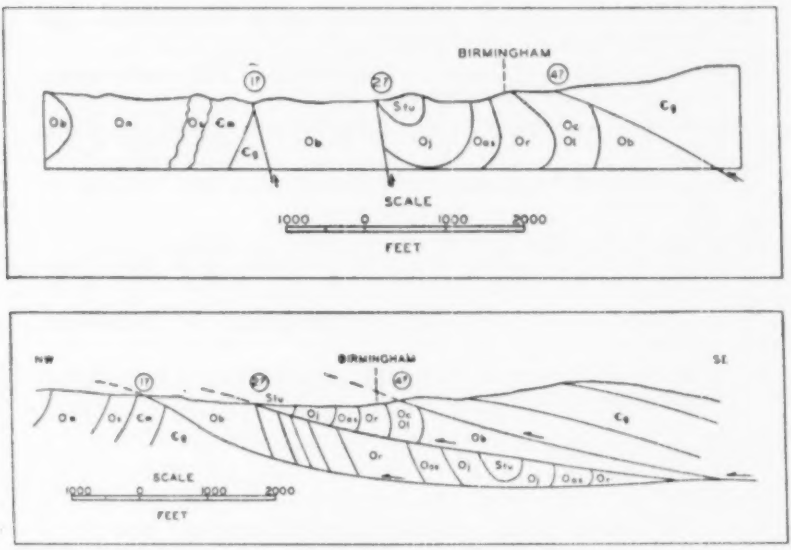

Figure 10. Structure sections across the Birmingham area, modified from Butts (1939). Upper section after Butts, lower section after Stose. For formational symbols see figure 2; for fault numbers (tentative) see figures 4 and 5.

ACKNOWLEDGMENTS

The author wishes to thank Professor Charles Merrick Nevin under whose direction this report was written. The writer appreciates the permission extended by Mr. Werden of the Pennsylvania Railroad and Mr. Little of the West

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THE VOLCANO PURACE

VICTOR OPPENHEIM

ABSTRACT. The volcano Puracé (4,596 meters) in southern Colombia has been active within historical times. Despite its geological importance little has been mentioned of its development in geological literature. Thus far the only published record of scientific observations at its crater were made by W. Reiss in 1868. The studies of the writer during two visits to the volcano, in 1947 and 1949, provide additional and recent data.

Puracé is at present the only active vent of a group of Pliocene volcanoes at the northern edge of the Cauca-Patia batholith in the Cordillera Central of Colombia. The rise of this batholith could be related to the emergence of the Cordillera Oriental Geosyncline to the East. The group of formerly very active volcanoes, of which Puracé forms part, are obviously located on tectonic lines of crustal weakness of this part of the Andes.

The eruptions of Puracé are of explosive character. The ejecta are of andesitic nature. The upper cone is built of andesitic lavas, bombs, lapilli and ashes. The lower part of the volcano is, however, made up of thick flows of dacite. The total height of the volcano is about 2,000 meters above the crystalline basement of the Cordillera Central.

The periodicity of eruptions of Puracé could not be established; however, it still appears very active. The explosive eruptions are of an intermittent character and in recent times were not accompanied by lava flows.

INTRODUCTION

THE volcano Puracé in the Department of Cauca, Colombia, is situated some 30 kilometers S. E. of Popayan (1,741 meters) in the upper Cauca valley at about 2° 20′ Lat. N. and 76° 25′ Long. W.

The exact altitude of the top of the volcano was given by different authors as varying from 4,900 to 4,700 meters. The writer's observations with aneroid have shown only 4,590 meters above sea level.

The volcano was ascended by the writer first on April 27, 1947, and again an attempt was made on June 11, 1949; this time accompanied by the writer's wife and the French geologist, de Sakowetch. On both occasions the volcano was in a state of near activity. On April 27, 1947, an eruption was witnessed by the writer at 7:00 A.M., some six hours previous to his ascent to the crater. At this time a column of steam and smoke which reached about 1,000 meters above the crater was visible. Lapilli from 5 to 10 millimeters in diameter were projected to a distance of over 10 kilometers from the crater, and ashes covered the streets of Popayan.

On June 11th an earthquake lasting about 30 seconds shook

the region and the village of Puracé at a distance of about 10 kilometers from the volcano. Due to exceedingly bad weather conditions, rain and storm, and the danger of pyroclastic materials, the party had to return from an elevation of approximately 4,000 meters without reaching the upper part of the cone. Before this ascent on May 26th, a violent explosive eruption of Puracé, also preceded by local seismic shock, caused the death of seventeen students of the University of Popayan who were attempting to reach the cone of the volcano. On both occasions there were no flows of lava and the eruptions were accompanied only by outbursts of gases, steam, volcanic bombs and rocks; large rock fragments which fell from considerable height were responsible for the casualties.

HISTORICAL DATA

Although Puracé has existed as a volcano since Pliocene times and evidently was active during historical times, the first mention of Puracé's activity was made by Humboldt in 1801, and later by Boussingault in 1831. Neither of the two has, however, left a written or graphic description of the volcano.

One of the earliest eruptions of Puracé is mentioned by A. Stuebel as having taken place on November 18, 1827. From his travels in later years it appears that Stuebel had not succeeded in reaching the crater despite his persistent efforts.

Wilhelm Reiss (1921), Stuebel's companion, with whom he studied and described many volcanoes of Ecuador and Colombia, was the first scientist to describe Puracé and its crater, following his ascent of November 18, 1868. Reiss refers to a number of violent eruptions of Puracé between December, 1849, and 1852. After these eruptions it appears that the top of the mountain had been considerably lowered. According to Reiss (1921) the inhabitants fled from the neighboring village and the town of Popayan was covered with a blanket of ashes. Many small eruptions which occurred since have not been recorded. Reiss also describes an eruption of October 4, 1869, which was accompanied by an earthquake and large mud-flow. There were no further eruptions recorded until May 25, 1885, when, according to the memory of the inhabitants, a catastrophic explosion of Puracé accompanied by an earthquake killed many people and destroyed many houses in the

region; the exact number of casualities was not recorded. The church of San José and many buildings in Popayan also were destroyed. A strong eruption of October 12, 1925, and a later one of November 5, 1925, are the first recorded activities of Puracé in this century. The observations were made by I. Friedlaender (1927) who also mentions another eruption of September, 1926, which was accompanied by flames and ashes. He observed the eruptions at a distance; his attempts to climb Puracé were, however, unsuccessful.

Subsequent eruptions were not recorded until April, 1946, when, according to the inhabitants of the village of Puracé, as related to the writer, a strong explosive eruption preceded by an earthquake shook the region, damaging the village church. The earthquake was felt also in Popayan.

The later recorded eruptions took place on April 27, 1947, when the writer ascended to the crater (fig. 1). The column

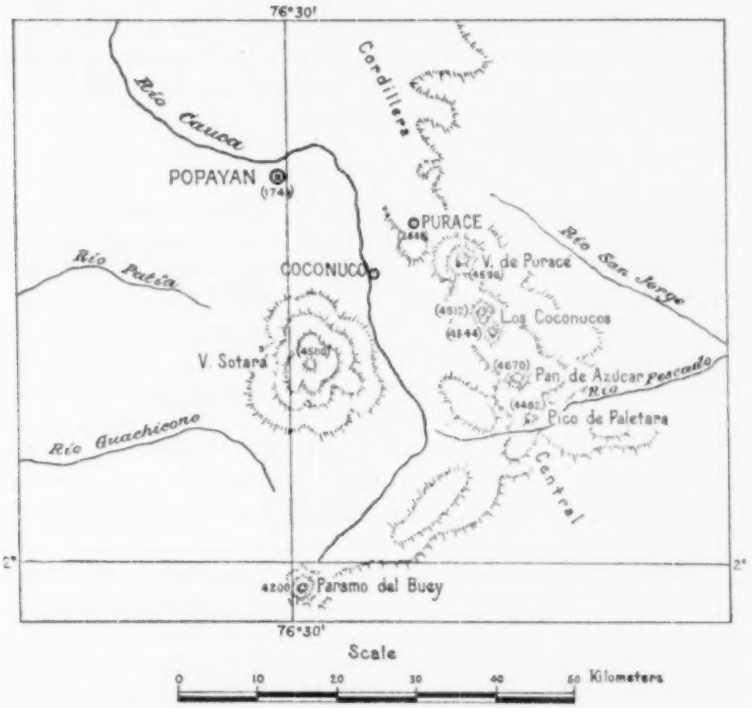

Fig. 1. Index map of Puracé Range, Colombia.

of smoke on this occasion rose to about 1,000 meters. A few days before this, ashes and lapilli fell to a distance of more than 10 miles from the volcano. On May 26, 1949, there occurred an explosion, again with an earthquake and great quantities of ashes and bombs. The earthquake of June 11th which was experienced by the writer and his party was probably also accompanied by an explosive eruption. This, however, could not be observed due to dense clouds that enveloped the mountain.

From the sporadic, available data of the activity of Puracé over more than a century it would appear that the volcano has only slightly diminished its explosive character since the time of its first-recorded eruptions.

The lack of systematic observations, such as should have been carried out considering the nearness of the volcano to villages and towns, make it impossible at present to determine the periodicity of the eruptions as well as the exact evolution of the cone and crater. The writer's observations of April, 1947, as compared to those of Reiss of November, 1868, give interesting material for the study of the development of Puracé during the last eighty years.

REGIONAL PHYSIOGRAPHY

Puracé forms the northern peak of a high volcanic range of the Cordillera Central, known as Sierra de Coconucos; Reiss (1921) also called it the Puracé Range. The volcano lies some 85 kilometers south of Nevado de Huila (5,750 meters), the highest volcanic peak of Colombia, and 25 kilometers northeast of the conspicuous volcanic peak of the recently active Sotará (4,580 meters). Eighteen kilometers southeast of Puracé lies the symmetrical volcanic cone of Pan de Azucar (4,670 meters). This appears to be quite extinguished. The Puracé Range extends about 25 kilometers to the southeast, the southernmost peak of the range being Pico de Paletara (4,482 meters).

Puracé, therefore, forms the apex of a group of three volcanoes of which it is the only active one at present since Sotará and Pan de Azucar are latent or dormant. The Puracé Range together with the volcano Sotará to the west of it border on both sides the uppermost valley of Rio Cauca, the southeastern headwaters of which descend from the range.

The southernmost sources of this great river originate, however, approximately 35 kilometers to the south at the Páramo del Buey, whence also descend the sources of Rio Magdalena, flowing to the east and Rio Patia, flowing to the south. This area of Colombia, where the largest river systems of the country originate, lies on a batholith of younger Tertiary age intruded into the older massive of the Cordillera Central. The volcanic range of Puracé as well as the active and dormant volcanoes of the region apparently represent magmatic outflows related to the rise of this batholith.

Rio San Francisco and Rio Vinagre descending from Puracé, both have deeply cut valleys. The valley of Rio Vinagre, which has its source at the cinder cone of the volcano, shows evidence of extensive mud-flows in its upper course. The waters of Rio Vinagre are highly sulphurous and according to some analyses carry over one percent of sulphuric acid and about one percent of hydrocloric acid. Several hot sulphur springs empty into the river. In its upper course the river bed is cutting thick sulphur layers at the foot of the volcano.

GLACIATIONS

Evidences of past glaciations around the volcano and on its lower flanks above an elevation of 3,500 meters are found in the form of typical U-shaped valleys, hanging valleys, glacier-polished surfaces and what might be remains of moraines. In the valley of Rio San Francisco glacial forms could be observed as low as 2,880 meters. This points to an intense glaciation that must have affected the whole range in Pleistocene times, and during the time that Puracé was most active. This confirms that Puracé is of pre-Pleistocene age.

Humboldt, at the beginning of the last century, as well as Reiss (1921) in 1869, described the range and particularly the peaks of Puracé and Pan de Azucar as being covered by an extensive snow cap. Likewise, within the memory of the old inhabitants of the region, ice and snow were carried by Indians to the town of Popayan for refreshment. Reiss, during his visit to the crater of Puracé, found about 70 meters of perpetual ice and snow on the crater's rim. But only patches of ice were reported at the top of the

mountain by 1934. At the time of the writer's visit to the crater there were found no traces of perpetual snow or ice; and a snow which fell on top of the mountain at this time melted instantly. The temperature at about 3:00 P.M. was 9° centigrade.

The lack of ice and snow on Puracé in recent times is largely due to the general process of deglaciation that is affecting the Andes (Oppenheim, 1948). The possible lowering of the crater due to successive explosions is also a consideration which, in the case of Puracé, should not be overlooked. On the other hand, there is evidence that recent eruptions have contributed to the growth of the volcanic cone.

GEOLOGY OF PURACE

Metamorphic crystalline slates are observable in the river valleys below the village of Puracé (2,648 meters) at an elevation of about 2,600 meters. These form the basement upon which is built the volcanic massive of Puracé. The height of the volcano above its foundation is thus about 2,000 meters, and its diameter at the base could be estimated at roughly 10 to 15 kilometers.

Dacite lavas of reddish color appear slightly inclined and in part lying almost horizontally, forming the lower part of the volcano up to an altitude of about 3,800 meters. They form a steep lava wall at the northwestern approach to the volcano. The truncated cone of Puracé above some 3,800 meters is made up of dark andesitic lava-flows interbedded with great amounts of andesitic tuffs, ashes, bombs and large blocks which form the pyroclastic cone of the volcano (fig. 2). Puracé therefore has a composite constitution. The dacitic shield volcano at its base is capped by an andesitic and pyroclastic cone. The andesitic lava-flows and tongues were apparently very viscuous and did not flow far from the crater despite the steep flanks of the volcano; the more recent flows were observed above 4,000 meters altitude.

On the northwestern side of the volcano and close to the main crater there appears part of a wall rising a little below the height of the crater rim. This may indicate the former cone of the crater or the wall of a parasitic crater that existed northwest of the present one. A small secondary crater is located

PLATE I

Fig. 1. Pyroclastic materials on the flanks of Puracé. In the center, cavity made by volcanic bomb (photograph by author).

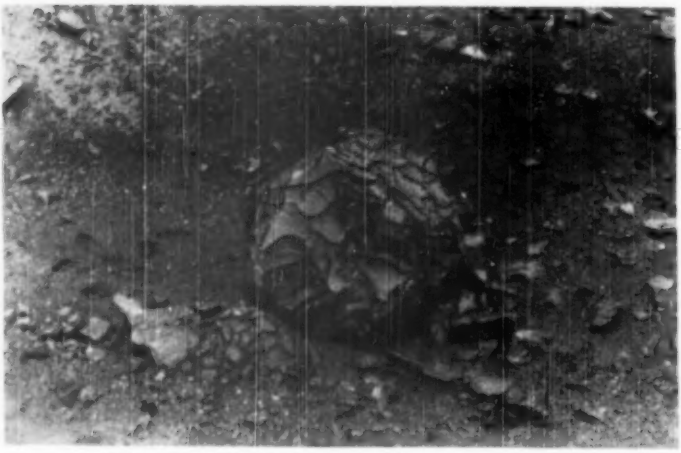

Fig. 2. Typical volcanic bomb of Puracé (photograph by author).

on the eastern flank of Puracé but could not be properly investigated.

The crater of Puracé, when observed in 1947 had a diameter of about 500 meters. It was totally made up of ashes, tuffs and other pyroclastic materials. The outer flanks have an inclination of about 30°. The inner walls, however, appeared

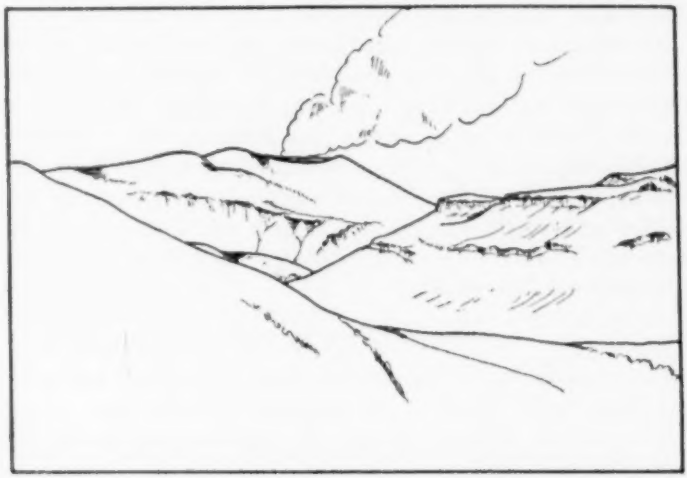

Fig. 2. View of Puracé in eruption in 1947 (from photograph by author).

much steeper and descended some 50 meters from the outer rim of the crater. At that level began the steep walls of the inner crater, issuing a column of steam, smoke and ashes.

Two fumaroles were observed some 150 meters from the rim of the crater on the outer western flank of Puracé. The smaller one, situated a little to the north and somewhat higher, was emitting steam in short periodic intervals simulating a steam engine. The second fumarole, a little lower and more to the south than the first one, showed a deep, wide cavity in the flank of the volcano and appeared surrounded with lava-flows, as well as layers of sulphur. It was emitting steam under less pressure than the first one.

The thick cover of pyroclastic materials forming the cone of Puracé consists predominantly of lapilli, with many large angular blocks of andesite which were torn out of the walls of the conduit of the volcano (plate 1, fig. 1). Some of the observed blocks were about 6 meters wide and 2 meters high. Upon falling,

these bombs formed cavities in the tuff-bed of the cone; some of them 4 to 5 meters wide and 2 meters deep. True lava bombs, although present, were not as frequent as the angular volcanic blocks (plate 1, fig. 2). Some of the bomb cavities appeared to have been made by blocks which were projected to the surface the morning of the ascent or a day or two previous, since the cinder beds were freshly disturbed.

The deeply cut gorge immediately below the second fumarole is the source of Rio Vinagre. Within a mile it opens into a deep cut in the western flank of the mountain, where are displayed effects of large, recent mud-flows.

When visited by the writer the cone was totally free of ice and snow, and the deep rib-like grooves described by Reiss (1921) at its top were absent. There was likewise no visible trace of the small lake on the floor of the crater as described by that author in 1868.

CHARACTER OF ERUPTIONS

The periodicity of the eruptions of Puracé has not as yet been determined. Most of the investigators who have studied it from a close distance during the past century found it in some form of activity.

On many clear mornings the workmen of a sulphur mine near Puracé, at an altitude of 3,600 meters, have reported seeing a tall column of smoke rising above the volcano. The old inhabitants of the region have observed that the Puracé eruptions are particularly frequent during the months of May and June; these are the rainiest months in this part of the country. It seems possible, therefore, that the explosive eruptions are particularly strong during these months because of infiltrations of meteoric waters into the crater.

The cause of the sporadic activity of the volcano in recent times would have to be looked for in the apparently continuous expansion of juvenile gases fed to the crater from some depth. These, however, do not seem to have been accompanied by lava-flows. Judging by the early description of the volcano the character of the explosions does not seem to have changed much in the last century. The fact that great mud-flows have accompanied eruptions in the past and do not occur today is due to the deglaciation which has been followed by the complete melting of the formerly existing snow cap. The eruptions,

however, are still accompanied by local earthquakes and by emissions of considerable masses of pyroclastic materials and bombs projected to great distances. It is also noteworthy that the fumaroles when observed by the writer in 1947 seemed to be as active as when described by Reiss 78 years ago.

All these factors of the past and present activity of Puracé tend to indicate that the volcano has not greatly reduced its explosiveness in the last century and, although it seems to have passed the stages of the magmatic eruptions of its earlier history, it can still be considered as one of the very active volcanoes of the Andes.

The fact that the other volcanic cones of the Puracé Range to the south, as well as the volcano Sotará to the west appear inactive in recent times, would suggest that the tectonic adjustment of this zone of crustal weakness of the Andes is nearing its completion. The activity of Puracé is, therefore, the only remnant of a formerly far greater plutonic activity in the Cordillera Central of Colombia.

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Bogotà, Colombia

A MOLLUSCAN FAUNA FROM THE TYPE SECTION OF THE TRUCKEE FORMATION

TENG-CHIEN YEN

ABSTRACT. Nineteen species and subspecies of freshwater mollusks are recorded from a saccharoidal limestone bed in Nevada. Previous records of the same formation exposed in this and its neighboring localities are reviewed. One genus and eight species and subspecies are herein described as new. This assemblage of molluscan species seems to indicate a Pliocene age of its enclosing rocks; it also indicates possibly a large size for the extinct body of water, bordered in part by muddy and in part by rocky shores; and the former existence of a rich growth of aquatic vegetation in the water.

A COLLECTION of invertebrate fossils, made by Dr. Daniel I. Axelrod, of the University of California at Los Angeles, from the type section of the Truckee formation in western Nevada, through the kindness of the collector, was submitted to me for examination and is the basis of the present paper. The fossil site, according to the information furnished by Doctor Axelrod, is shown on the U. S. Geological Survey's Carson Sink topographic sheet, "two miles north of the triangle marking the position of the Desert Queen Mine, which lies in the northeastern corner of the Hot Springs Mountains." No specific data concerning the stratigraphic position of the fossil bed were supplied.

The locality is evidently that of the fossiliferous deposit described by King (1878, p. 416) as his no. 3 bed of the Truckee group, which bed consists of saccharoidal limestone, 60 feet in thickness and bearing a rich content of freshwater mollusks. Meek (1870) described King's collection, citing the locality as "Hot Springs Mountains, at Fossil Hill, Idaho Territory." Meek later (1877) recorded this same group of species as from "Fossil Hill, Kaw-soh Mountains, Nevada." After a full consideration of the existing data, Reeside has pointed out (in Henderson, 1935, p. 49) that Hot Springs Mountains and Kaw-soh Mountains are identical, and the present collection of mollusks is undoubtedly from the same area. Meek recorded the following species:

Sphaerium rugosum Meek, 1870
Sphaerium idahoense Meek, 1870
Ancylus undulatus Meek, 1870

Carinifex (*Vorticifex*) *binneyi* Meek, 1870
Carinifex (*Vorticifex*) *tryoni* Meek, 1870
Carinifex (*Vorticifex*) *tryoni* var. *concava* Meek, 1870
Melania? *sculptilis* Meek, 1870
Melania? *subsculptilis* Meek, 1870

C. A. White (1883) recorded a group of freshwater molluscan species from the "Truckee Group," exposed "about 50 miles below Salmon Forks, Snake River," Idaho. In addition to the seven species noted in Meek's list above, White reported the following additional species of gastropods:

Melania taylori Gabb
Lithasia antiqua Gabb
Latia dalli White

These additional species have been later reported from the Idaho formation by Dall (1924) and Yen (1944).

COMPOSITION OF THE FAUNA AND ITS HABITAT

The molluscan fauna from the type section of the Truckee formation, so far identified in the present collection, consists of the following species:

Sphaerium rugosum Meek
Valvata cf. *V. incerta* Yen
Valvata truckeensis, n. sp.
Amnicola truckeensis, n. sp.
Fluminicola yatesiana inflata, n. subsp.
Hydrobia truckeensis, n. sp.
Lacunorbis nevadensis, n. gen. and sp.
Goniobasis sculptilis (Meek)
Goniobasis cf. *G. arnoldiana* Pilsbry
Lanx undulatus (Meek)
Gyraulus sp. undet.
Menetus sp. undet.
Vorticifex tryoni (Meek)
Vorticifex tryoni concavus (Meek)
Vorticifex tryoni planus, n. subsp.
Vorticifex menetoides, n. sp.
Vorticifex globosus, n. sp.
Vorticifex binneyi (Meek)

The fossils are imbedded in a soft calcareous rock of coarse texture. In the course of preparation of the specimens, two kinds of matrix have been noted: one of creamy color containing dominantly species of *Vorticifex*, *Lacunorbis*, and *Lanx*; and a second pale gray in color and rich in species of *Goniobasis*. They seem to represent two different horizons or two distinct facies. Further investigation in the area would be required to reveal the significance of the apparent difference in the molluscan assemblages.

An assemblage rich in species and prolific in individuals generally implies a large size for the extinct body of water in which the fauna lived. The molluscan elements also seem to show that it was probably bordered in part by muddy shores and in part by stony shores. Considerable range of variation in size, sculpture, and altitude of shells in several of the species of gastropods here contained may possibly indicate different velocities of current and fluctuations of hydrogen-ion concentration of the water.

The rissoid and planorbid snails abundant in this fauna generally require a habitat area with a rich growth of an aquatic flora, either masses of filamentary algae or leafy plants, or both. Species of *Amnicola* and *Fluminicola* generally live on submerged vegetation that may be exposed to some current and on stems and leaves of reeds near the shore. Species of *Vorticifex*, *Menetus*, and *Gyraulus* primarily live on submerged plants of muddy and stony bottoms, especially among the vegetation near the shore. These planorbid snails are not rheophilous, but they can exist in moderate current. The freshwater limpets, such as species of *Lanx*, prefer a rocky bottom with vegetation in still water, though they may also exist in places where there is a slight current. Since the limpets live on diatoms and other algae as their food, the presence of such snails over the area may well imply also the presence of such lower plants.

The pleuroceratid forms, such as those of *Goniobasis*, may be variable in sculpture according to the hydrogen-ion concentration of the water. In general they are considered to be fluviatile forms, but they have been found to exist equally well in large lakes. Numerous specimens of *Goniobasis sculptilis* in the present collection are found to contain shells of young rissoid and planorbid species. It seems certain that these

pleuroceratid shells were drifted ashore in quantity by currents, and the shore snails accidentally crept into the dead shells.

The new genus *Lacunorbis* will give no particular indication of its habitat until its relationships with Recent genera are better established. Since it is found in the present assemblage, it is probably a form of lacustrine habitat.

AGE OF THE DEPOSIT

The Truckee group was assigned by King (1878, p. 412) to a Miocene age. At the time (1870) Meek described the species of mollusks in King's collection, he considered it to be "apparently of Miocene or later age." This age assignment has been much questioned and discussed by authors during the last three-quarters of a century, but the deposit has been placed within the range of Meek's "Miocene or later."

On the evidence of the molluscan species, the assignment to a Miocene age seems to be favored only by presence of abundant individuals of *Vorticifex tryoni* and its varieties. These forms have been recorded from Miocene beds in southeastern Idaho (Yen 1946). However, the species has also been recorded from a number of Pliocene localities in Idaho, Utah, and Nevada, and its value as an age indication is thus reduced. On the other hand, *Vorticifex tryoni* and its varieties are here recorded together with *V. binneyi* and *Lanx undulatus*. A similar assemblage of species has been reported from the Idaho formation, of Pliocene age. Moreover, species of *Valvata*, *Amnicola*, *Fluminicola*, *Hydrobia*, and *Goniobasis* found in the present collection show close resemblance to the congeneric forms that have been described from Pliocene beds in Utah and the Tulare beds in California. Such morphological resemblance may well imply closeness in age.

It is clear then on the evidence of a few identifiable species of gastropods that the age of the type section of the Truckee formation is more likely to be Pliocene than Miocene. This conclusion seems to have been anticipated, however, in a quite noncommittal statement by Buwalda (1914), who on the evidence of a proboscidean tooth infers that the typical Truckee is "middle or upper Miocene or later." His statement seems to have been endorsed later on by Simpson (1933), who also considers that the Truckee beds are "at least as young as the middle Miocene, probably considerably younger."

SYSTEMATIC ACCOUNT OF THE MOLLUSCAN SPECIES

Family Sphaeriidae

Sphaerium rugosum Meek

Pl. 1, fig. 1.

Acad. Nat. Sci. Philadelphia Proc., 22, p. 56, 1870; U. S. Geol. Expl. 40th Par. Rept. 4(1), p. 182, pl. 16, figs. 2, 2a, 2b, 1877.

A number of closed shells and single valves that represent different stages in development seem to agree well with this species. The better-preserved specimens show distinctly the concentric growth lines noted by Meek. The illustrated specimen represents a young stage with well-preserved sculpture.

EXPLANATION OF PLATE

Fig. 1. Sphaerium rugosum Meek. X2.

Fig. 2. Valvata cf. V. incerta Yen. X6.

Fig. 3. Valvata truckeensis Yen, n. sp. X6. Holotype.

Fig. 4. Amnicola truckeensis Yen, n. sp. X6.
4. Holotype.
4a, 4b. Paratypes.

Fig. 5. Fluminicola yatesiana inflata Yen, n. subsp. X4.
5. Holotype.
5a. Paratype.

Fig. 6. Hydrobia truckeensis Yen, n. sp. X6. Holotype.

Fig. 7. Lacunorbis nevadensis Yen, n. gen. and sp. X6. Holotype.
7. apertural view.
7a. apical view.
7b. basal view.

Fig. 8. Goniobasis sculptilis (Meek).
8. an adult form. X1.
8a. a young form with sculpture preserved. X2.
8b. a young form with sculpture not preserved. X4.

Fig. 9. Goniobasis cf. G. arnoldiana Pilsbry. X2.

Fig. 10. Lanx undulatus (Meek).
10 and 10a. adult specimens. X1.
10b. a young form having higher altitude of shell. X2.

Fig. 11, 11a. Menetus sp. undet. X6.

Fig. 12, 12a. Vorticifex tryoni (Meek). X1.

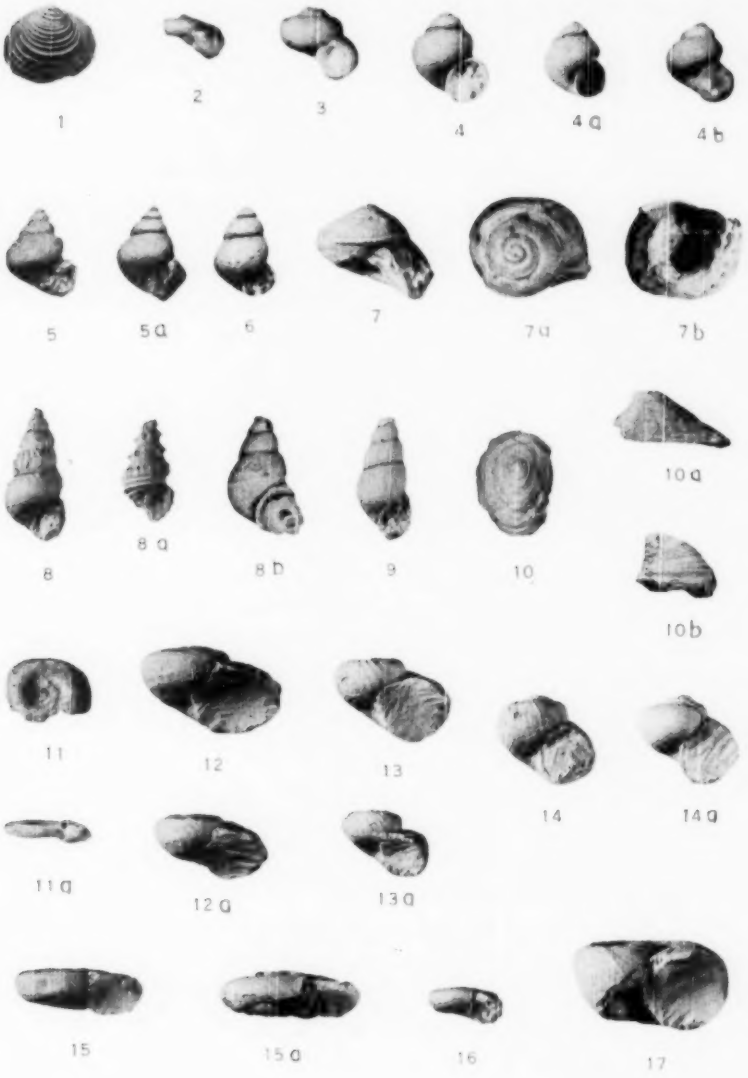
Fig. 13, 13a. Vorticifex tryoni concavus (Meek). X1

Fig. 14. Vorticifex globosus Yen, n. sp. X1.
14. Holotype.
14a. Paratype.

Fig. 15. Vorticifex menetoides Yen, n. sp. X2.
15. Holotype.
15a. Paratype.

Fig. 16. Vorticifex tryoni planus Yen, n. subsp. X1. Holotype.

Fig. 17. Vorticifex binneyi (Meek). X1.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Figured specimen: U.S.N.M. 560432; additional specimens: U.S.N.M. 560433.

Family Valvatidae

Valvata cf. V. incerta Yen

Pl. 1, fig. 2.

Jour. Paleontology, 21(3), p. 272, pl. 43, figs. 4a-c, 1947.

This form is more planorboid in outline than *V. incerta*, which was described from a Pleistocene deposit of Utah, and it is obscurely angulated along the periphery of the body whorl. The illustrated specimen is well preserved, whereas a few other examples retain only their early whorls. It is probably a distinct species of *Valvata*, but the material available at present does not permit a full description of a species.

Figured specimen: U.S.N.M. 560434; additional specimens: U.S.N.M. 560435.

Valvata truckeensis, Yen, n. sp.

Pl. 1, fig. 3.

This species resembles the one recorded as *Valvata* sp. undet. from a Miocene deposit exposed near Montpelier, Idaho (Yen, 1946, p. 488, pl. 76, fig. 3). It is characterized by its small size (1.9 mm. in altitude, 2.0 mm. in width, with a little over 3 gently convex whorls), globose outline of shell, elevated spire, descending body whorl, and circular aperture; its umbilicus is about one-third the diameter of the shell.

It is smaller in size and has less convex whorls and wider umbilicus than the Miocene form recorded from Montpelier, Idaho.

Holotype: U.S.N.M. 560436; paratypes: U.S.N.M. 560437.

Family Amnicolidae

Amnicola truckeensis, Yen, n. sp.

Pl. 1, figs. 4, 4a, 4b.

Shell small in size, subglobose in outline, having a short but elevated spire and an inflated body whorl. Whorls roundly convex, moderately rapidly increasing in size; surface bearing fine lines of growth. Aperture cardiform in outline, descending, barely attaching to the preceding whorl. Peristome continuous and thin; inner lip margin slightly expanded. Umbilicus narrow but open.

Measurements (given in mm. for this and all the following species): Shell 2.4 in altitude, 2.0 in width; aperture 1.0 in height, 0.7 in width; 3¾ whorls.

This species resembles *Amnicola longinqua* Gould but differs by its more globose outline, smaller size, and shorter spire. *Amnicola longinqua* has been frequently reported from the Recent fauna as well as from Pleistocene beds.

Holotype: U.S.N.M. 560438; paratypes: U.S.N.M. 560439; figured paratypes: U.S.N.M. 560447 and 560448.

Fluminicola yatesiana inflata Yen, n. subsp.

Pl. 1, figs. 5, 5a.

This subspecies differs from the typical form, which was originally described from Pliocene beds in California, by its much smaller size, with similar number of whorls, more rapidly inflated body whorl, and more acute angle of spire. It differs from *F. y. utahensis* Yen, which was described from Pliocene beds in northern Utah (1947, p. 273, pl. 43, fig. 6), by its more strongly convex whorls and more inflated body whorl. The holotype is 3.5 mm. in altitude, 2.8 mm. in width, and has 4½ whorls.

Holotype: U.S.N.M. 560440; paratypes: U.S.N.M. 560441; figured paratype: U.S.N.M. 560442.

Hydrobia truckeensis, Yen, n. sp.

Pl. 1, fig. 6.

Shell minute in size, subovate in outline; spire greater than the body whorl. Whorls strongly convex, moderately rapidly increasing in size and bearing fine lines of growth. Aperture descending, cardiform in outline, and barely attached to the penult whorl. Peristome thin and continuous. Umbilicus narrowly perforate.

Altitude of shell	2.1	2.0
Width of shell	1.3	1.3
Diameter of aperture	0.6	0.6
Number of whorls	4	3½

The size and outline of this species approach closely those of *Hydrobia andersoni* (Arnold), a Tulare species from California. However it differs by having fewer whorls and shorter spire.

Holotype: U.S.N.M. 560449; paratypes: U.S.N.M. 560450.

Lacunorbis Yen, n. gen.

Shell trochoid in outline, perspectively umbilicated, with a few tubular and closely coiled whorls, more or less carinated along the periphery. Aperture angulate-ovate in outline, descending, and more or less attached to the penult whorl.

Genotype: *Lacunorbis nevadensis* Yen, n. sp.

The new genus is reminiscent of *Brannerillus* Hannibal, from Miocene and Pliocene deposits in western North America, and *Cochliopa* Stimpson, in the Recent fauna distributed over California, Texas, and Central America. The genus is characterized by its trochoid outline, perspective umbilicus, and its tubular whorls.

Lacunorbis nevadensis Yen, n. sp.

Pl. 1, figs. 7, 7a, 7b.

Shell of small size, about 3 mm. in diameter, with a slightly raised apical whorl and conically elevated spire. Whorls moderately rapidly increasing in size, tubular, and closely coiled, with their surface slightly convex, strongly carinated at the periphery, and bearing fine lines of growth. Aperture descending, barely attached to the preceding whorl, angularly ovate in outline. The umbilicus is about two-thirds of the diameter of the shell.

Altitude of shell	2.5	2.0	1.7
Width of shell	3.0	2.8	2.7
Diameter of aperture	0.8	0.6	0.5
Diameter of umbilicus	1.5	1.4	1.2
Number of whorls	4	3¼	3¼

The species is characterized by its small size, with closely coiled whorls and strongly carinated periphery.

Holotype: U.S.N.M. 560443; paratypes: U.S.N.M. 560446; figured paratypes: U.S.N.M. 560444 and 560445.

Family Pleuroceratidae

Goniobasis sculptilis (Meek)

Pl. 1, figs. 8, 8a, 8b.

Acad. Nat. Sci. Philadelphia Proc., 22, p. 58, 1870; U. S. Geol .Expl. 40th Par. Rept. 4(1), p. 195, pl. 17, fig. 8, 1877.

This is a quite common species in the Truckee beds. The present collection contains specimens representing several stages in development. The width of shell seems to be quite variable, a few examples being more slender in outline than the typical forms.

Figured specimens: U.S.N.M. 560451, 560452 and 560453; additional specimens: U.S.N.M. 560454.

Goniobasis cf. G. arnoldiana Pilsbry

Pl. 1, fig. 9.

Nautilus, 48, p. 15, 1934; Acad. Nat. Sci. Philadelphia Proc., 86, p. 547, pl. 18, figs. 6, 6a, 7, 1935.

Five specimens in the collection are comparable to *Goniobasis arnoldiana*, but they differ from the Tulare species from California by their much smaller size, more slender outline, and more convex whorls. They probably represent a distinct species, but a full description will have to be based on specimens in more perfect state of preservation.

Figured specimen: U.S.N.M. 560455; additional specimens: U.S.N.M. 560456.

Family Lancidae

Lanx undulatus (Meek)

Pl. 1, figs. 10, 10a, 10b.

Acad. Nat. Sci. Philadelphia Proc., 22, p. 57, 1870; U. S. Geol. Expl. 40th Par. Rept. 4(1), p. 186, pl. 17, fig. 12, 1877. (*Ancylus*)

This is one of the common species of the Truckee formation and is represented by many specimens in the present collection. The available examples show a range of variation in altitude of shell. This species is also reported from several localities in the Idaho formation, of Pliocene age, in the southern part of Idaho.

Figured specimens: U.S.N.M. 560458 and 560459; additional specimens: U.S.N.M. 560460.

Family Planorbidae

Gyraulus sp. undet.

About a dozen rather imperfect specimens represent this small form of *Gyraulus* in the collection. Most of them consist of 2 to 3 gently convex and rapidly increasing whorls. No characteristic features are noticeable, and their specific identity is at present undeterminable.

U.S.N.M. 560461.

Menetus sp. undet.

Pl. 1, figs. 11, 11a.

This form is of nearly the same size as the preceding one,

1 to 1.5 mm. in diameter of shell, but it differs by having less rapidly increasing whorls and being distinctly carinated along the periphery. The differentiation of the two forms in the same fossil bed is readily effected. Its occurrence is less common in the deposit than that of the preceding species.

Figured specimen: U.S.N.M. 560462; additional specimens: U.S.N.M. 560463.

VORTICIFEX MEEK

The genus *Vorticifex* Meek is represented by species from the late Tertiary beds in Nevada and Idaho, so far as the previous records are known. A few forms that have been referred to this genus may belong to *Carinifex* or other genera.

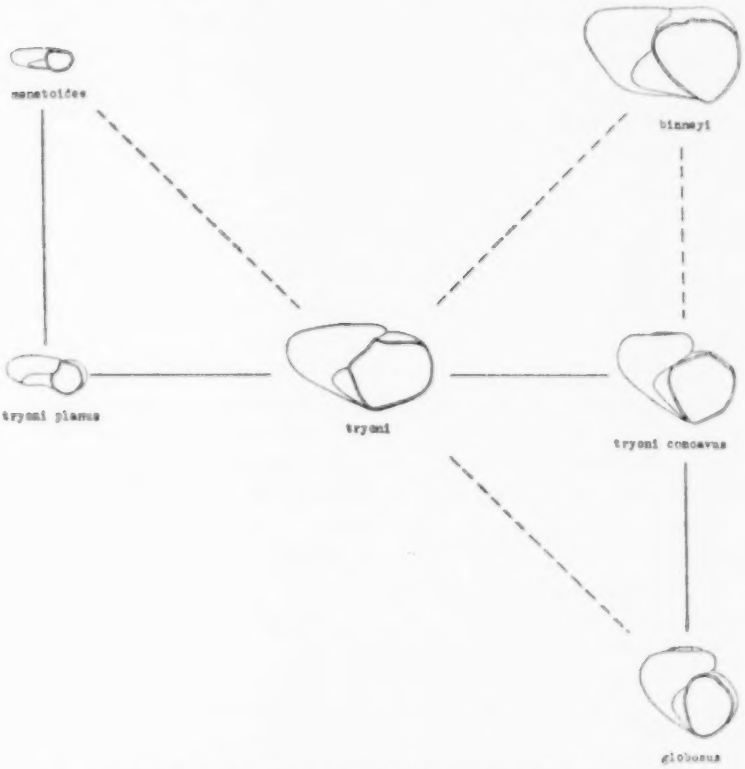

Fig. 4. Speciation of *Vorticifex* Meek — the illustrations are natural size, solid line shows possible derivations of the "elementary species," uncertain connections of species are indicated by broken line.

This apparently extinct genus is represented in the present fauna by the six species and subspecies described below. All these forms are apparently more or less related, but they are sufficiently differentiated from each other by distinct features of both adult and young stages. The speciation of these forms is illustrated by figure 1, in which the solid line indicates the relationships of all the forms involved, on the basis of similarity in their morphological features, while the broken line indicates uncertainty of connections.

Vorticifex tryoni is represented in the present collection by more individuals than any one of the remaining five forms. *V. t. concavus* and *V. menetoides* rank next in abundance, and the other three all have several to a score of examples in the collection. The greater number of individuals of *V. tryoni* imply that it is possibly an "elementary species" of the genus. Others seem to be related to it, and some may possibly be evolved through hybridization.

Vorticifex tryoni (Meek)

Pl. 1, figs. 12, 12a.

Acad. Nat. Sci. Philadelphia Proc., 22, p. 59, 1870; U. S. Geol. Expl. 40th Par. Rept. 4(1), p. 188, pl. 17, fig. 10, 10a-b, 1877.

This species is one of the dominant forms in the Truckee beds. It is represented by a large number of individuals. The peripherial angulation ranges from distinct to obscure, and the typical form is rather rounded at the periphery. The younger individuals have a descending aperture large in proportion to the size of the shell and are readily separable from the young individuals of the related forms. Meek's variety *ventricosa* (1870, p. 60) does not bear sufficiently distinct features to warrant a separation. The body whorl of this species is more or less ventricose, and its appearance is somewhat determined by the outline along the periphery of the body whorl, whether angulated or smoothly rounded.

Figured specimens: U.S.N.M. 560464 and 560465; additional specimens: U.S.N.M. 560466 to 560469.

Vorticifex tryoni concavus (Meek)

Pl. 1, figs. 13, 13a.

Acad. Nat. Sci. Philadelphia Proc., 22, p. 60, 1870; U. S. Geol. Expl. 40th Par. Rept. 4(1), p. 189, pl. 17, fig. 10c, 1877.

This form differs from the species by having a sunken apical whorl and subsequent whorls more strongly convex, more rapidly increasing in size. It bears more or less strongly developed riblets in addition to the distinct lines of growth.

Figured specimens: U.S.N.M. 560470 and 560471; additional specimens: U.S.N.M. 560472.

Vorticifex tryoni planus Yen, n. subsp.
Pl. 1, fig. 16.

This form is differentiated from *tryoni* s. s. and *t. concavus* by its much smaller size, more planorboid outline, much less rapid increase in size of whorls, and its wider umbilicus.

Altitude of shell	6.2	5.5
Width of shell	12.5	11.2
Height of aperture	5.5	6.0
Width of aperture	4.8	5.0
Diameter of umbilicus	3.0	3.0
Number of whorls	4¼	4

Holotype: U.S.N.M. 560473; paratypes: U.S.N.M. 560474.

Vorticifex menetoides Yen, n. sp.
Pl. 1, figs. 15, 15a.

Shell of planorboid outline, comparatively small in size for the genus. The whorls are rather flatly convex and rapidly increase in size. The body whorl is laterally inflated and slightly descending, which features produce a gently convex appearance of the shell in apical view. The periphery is obscurely angulated and roundly convex at the base. The sculpture consists of lines of growth and distinct but weak riblets. Aperture transversally ovate, peristome thin and continuous. Umbilicus moderately wide.

Altitude of shell	3.7	4.0
Width of shell	9.1	10.0
Height of aperture	3.1	3.6
Width of aperture	4.2	4.2
Diameter of umbilicus	3.0	3.0
Number of whorls	4½	4

This species differs from *V. t. planus* by its much smaller size, more flatly planorboid outline, and wider umbilicus. It is represented by several score of examples in the present collection, and they are found in association with *V. tryoni* and related forms.

Holotype: U.S.N.M. 560475; paratypes: U.S.N.M. 560477; figured paratype: U.S.N.M. 560476.

Vorticifex globosus Yen, n. sp.
Pl. 1, figs. 14, 14a.

Shell globose in outline, with low but elevated spire and inflated body whorl. Whorls roundly convex, rapidly increasing in size, rounded at the periphery and obscurely angulated at the base. The sculpture consists of fine growth lines and strong riblets. Aperture descending, pyriform in outline; peristome thin and continuous, umbilicus moderately open.

Altitude of shell	13.5	13.0
Width of shell	15.0	15.0
Height of aperture	9.0	9.5
Width of aperture	8.0	8.0
Diameter of umbilicus	4.0	4.0
Number of whorls	4	4

This species differs from *V. tryoni* by its smaller size, more globose outline, more roundly convex whorls, and decidedly descending aperture. It is characterized by its globose outline, small size, and narrowly opened umbilicus. It has some features of both *V. tryoni* and *V. t. concavus*.

The elevation of the spire seems to be variable, though it never becomes very depressed. The aperture of the younger forms is nearly circular in outline.

Holotype: U.S.N.M. 560478; paratypes: U.S.N.M. 560480; figured paratype: U.S.N.M. 560479.

Vorticifex binneyi (Meek)
Pl. 1, fig. 17.

Acad. Nat. Sci. Philadelphia Proc., 22, p. 59, 1870; U. S. Geol. Expl. 40th Par. Rept. 4(1), p. 187, pl. 17, figs. 11, 11a, 1877.

This species is characterized by its large size (the largest example in the present collection is 20.0 mm. in altitude of shell, 27.0 in width; 14.2 in height of aperture and 14.0 in its width; and has a little over 4 whorls), carination along the periphery and also around the umbilicus, and very rapidly increasing whorls. The younger forms have an excavated and widely open umbilicus, more or less flatly depressed spire, and a descending aperture.

Figured specimen: U.S.N.M. 560481; additional specimens: U.S.N.M. 560482.

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THE FAUNA AND CORRELATION OF THE McCRANEY LIMESTONE OF IOWA AND ILLINOIS

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ABSTRACT. Recent collections of fossils from the McCraney limestone in Iowa and Illinois and study of several sections of the Kinderhook strata along the Mississippi River have yielded new facts concerning the age and relationship of the terrane. Evidences cited favor the correlation of the McCraney with the Louisiana formation. Faunally, lithologically and stratigraphically the two terranes seem to be members of the same body of limestone.

INTRODUCTION

IN the basal Kinderhook beds of Iowa and Illinois occurs the McCraney limestone, generally lithographic, and with characteristic physical appearance. Its stratigraphic position with reference to other Kinderhook beds and its correlation have been subject to various interpretations in the past. The present paper, the result of investigations made for the Iowa Geological Survey in 1946-47 and the writer's own studies, presents new evidence which may aid in settling the problem satisfactorily.

In northeast Missouri in the vicinity of the Mississippi River and in west-central Illinois a similar limestone has long been known and its extensive fauna studied by several investigators. It was called the Louisiana limestone by Keyes (1892, p. 289). Rowley described the formation as it occurs in Pike County, Missouri, and gave diagnoses and illustrations of many of its fossils. Weller (1914) described and illustrated many of its brachiopods. Williams has lately given a monographic survey of the formation and of its fauna. He considered the formation to be lower Mississippian in age and gave a complete summary of the evidence therefor.

The Louisiana limestone has generally been considered to be a member of the Kinderhook series of the Mississippian system. Recently Branson and Branson and Mehl, chiefly on the basis of the occurrence of the conodont genus, *Icriodus*, have suggested that the limestone is upper Devonian in age.

The McCraney limestone in the Kinderhook sections at Burlington and Kinderhook has been studied by a number of

geologists. Keyes (1895, p. 437) considered it as distinct from the Louisiana limestone which he states feathers out before reaching the Burlington area. Weller (1900, p. 79) in his studies of the fauna of the Kinderhook suggested that the McCraney (bed 4 of Burlington section) "may be considered with a fair degree of certainty, as the northern extension of the Louisiana limestone". But later (1901, p. 209) he casts doubt on this conclusion by stating that the bed in question "had little or nothing to suggest its correlation with the Louisiana limestone".

Moore studied this limestone at Kinderhook, Illinois, and at Burlington, Iowa, and came to the conclusion (1928, p. 21) that it and the Louisiana limestone were distinct terranes. Consequently he termed the lithographic limestone at Kinderhook, Illinois, the McKerney from a creek nearby and included it along with the English River siltstone and Maple Mill shale as members of the Hannibal formation. The name was later found to be more properly McCraney (Weller and Sutton, 1940, p. 784).

Laudon (1931, p. 369) in his studies of the Kinderhook beds of Iowa designated the McCraney limestone as the *Paraphorhynchus* zone of the North Hill member of the Hampton formation. He rejected the correlation of the limestone with the Louisiana stating that "the fauna, however, shows definitely that this is not true." He suggested (p. 371) its lithologic similarity to upper ledges of the Chouteau at Newark, Missouri. However the fauna of this bed as listed by Moore (1928, p. 63, zone 4) shows few or no typical McCraney fossils.

Williams (1943) gave in considerable detail the various opinions of and evidence for and against the correlation of the McCraney with the Louisiana and he concluded with Moore and Laudon that the McCraney is younger than Louisiana. He stated, however, that the correlations of Moore are based on incomplete evidences, many of them conflicting. He suggested that new facts will have to be discovered in order to correlate the Kinderhook beds at Kinderhook, Illinois, at Louisiana, Missouri and at Burlington, Iowa, with any degree of assurance.

L. A. Thomas (1949) has recently discussed the McCraney and Louisiana limestones incidental to his study of conodonts of several Mississippian formations of southeast Iowa. He

concludes that the McCraney cannot be correlated with the Louisiana limestone on grounds which to the present writer are not established beyond dispute.

The foregoing summary is sufficient to indicate the present confusion in the minds of geologists regarding the age and correlation of various strata near or above the Devono-Mississippian boundary. Different lines of evidence apparently have led to divergent opinions of the stratigraphic position of the same formation. Especially is this true of the McCraney-Louisiana problem. The writer has recently secured evidences, both stratigraphic and faunal, which lead him to correlate the two beds. The faunal evidence is considered first.

Fauna of the McCraney Limestone

A few macrofossils were collected by H. G. Hershey and the writer in the quarry north of Kinderhook, Illinois, where the McCraney lies directly beneath the Burlington limestone and above the English River siltstone. A few others were found in the limestone in outcrops farther to the north. In general, search for macrofossils in the Illinois area proved disappointing. Therefore, samples of shaly and weathered material were collected from between layers of the McCraney in several localities. The first is from the larger quarry in the NE 1/4 sec. 15, T. 4 S., R. 7 W., the second from an outcrop on the first creek north of Pigeon Creek and the last two from two places in Seehorn Hollow in SE 1/4 NW 1/4, sec. 31, T. 3 S., R. 7 W. and .2 mi. down the creek.

The complete fauna secured in Illinois from the McCraney is as follows:

Macrofossils

Syringothyris hannibalensis (Swallow)

This may be *S. halli* which differs, as Weller remarks, only in size.

Chonetes ornatus Shumard

Dozens on slabs embedded in matrix.

Paraphorhynchus striatocostatum (M. & W.)

Crushed examples poorly preserved, but showing the typical external markings.

Rhynchopora pustulosa (White)

Avonia pyidata (Hall)

This species is reported by Weller.

Microfauna

Locality 1, Kinderhook quarry

Selenella pediculus Rowley
Ambocoelia louisianaensis Williams
Crinoid columnals

Locality 2, first creek north of Pigeon Creek

Selenella pediculus Rowley
Ambocoelia louisianaensis Williams
Crania dodgei Rowley
Echinoid spines
Blastoid plates
Crinoid columnals

Locality 3, Seehorn Hollow

Selenella pediculus Rowley
Ambocoelia louisianaensis Williams
Crania dodgei Rowley
Chonetes ornatus Shumard
Schuchtertella louisianaensis Williams
One small example with large ribs is placed in the species.
Strophalosia beecheri Rowley
Ambocoelia minuta White
Hybochilocrinus americanus Rowley
A dozen well-preserved examples, some showing plates and oral structures.

Platycrinus radials
Poteriocrinus? basals

Common echinoderm fragments including crinoid columnals; echinoid spines, striated and similar to those in Louisiana limestone; sievelike holothuroid plates; blastoid ambulacra and plates similar to those illustrated by Williams as *Mesoblastus*.

Ostracodes

The McCraney limestone at Burlington, Iowa, has been investigated by Weller (1900) and Van Tuyl (1928). The first lists these macrofossils:

Chonopectus fischeri (N. and P.)
Paraphorhynchus striatocostatum (M. and W.)
Allorhynchus heteropsis (Win.)
Rhynchonella unica Winchell
Rhynchopora pustulosa (White)

Syringothyris halli Winchell
Chonetes gregarius Weller

Van Tuyl adds
Allorisma sp.
Schizodus sp.
Chonetes sp.

The writer found *Chonetes ornatus* Shumard to be rather abundant in a quarry on the south side of North Hill, at Burlington, Iowa. Samples of interlayer material were collected at the North Hill and Starr Cave localities. Only the samples from the latter place proved to carry recognizable fossils. From them were recovered:

Selenella pediculus Rowley
Ambocoelia minuta White
Bembexia minimus Rowley
Crinoid columnals
Echinoid spines

The species, though few in number, are similar to those secured from the McCraney beds at Kinderhook, Illinois, and indicate that the McCraney beds at Burlington are correctly correlated with those in the latter area.

In Franklin county, Iowa, a limestone similar in appearance to the McCraney and having the same stratigraphic situation was recently studied by the writer. It has a fauna demonstrating that it is the northward extension of the McCraney limestone of the Burlington area. Macrofossils are common and well preserved and the following species were identified:

Dictyoclostus sp.
Linoproductus ovatus (Hall)
Paraphorhynchus striatocostatum (M. and W.)
Camarotoechia cf. *tuta* Miller
Rhynchopora rowleyi Weller
Syringothyris hannibalensis (Swallow)
Cranaena sp.
Schellwienella sp.
Chonopectus fischeri (N. and P.)
Torynifer sp. A mold of an exterior.
Grammysia hannibalensis Shumard
Bellerophon sp.

Platyceras sp.
Aviculopecten cf. *marbuti* Rowley

Samples also were collected of the interlayer material and were found to carry a fairly good microfauna. Among the forms are:

Ambocoelia minuta White
Ambocoelia louisianaensis Williams, common.
Selenella pediculus Rowley, common.
Chonetes ornatus Swallow, a brachial valve.
Allorhynchus cf. *currei* Rowley, a small example.
Crinoid columnals, common.
Crinoid plates of two types, including *Platycrinus* sp.
Blastoid remains similar to *Mesoblastus* sp.
Echinoid spines and plates.
Holothuroid plates.

Fauna of the Louisiana Limestone

The Louisiana limestone at Hannibal and Louisiana, Missouri, was studied at intervals over several years and a small fauna collected. Additional examples of a number of species were given to the writer by the late R. R. Rowley as well as nearly a pint of washed interlayer material abounding in microforms. The exposure of Louisiana near the Methodist Church at Hamburg, Illinois, yielded many fossils in a short period of time. Especially prolific is the microfauna secured there which contains a number of minute species described by Rowley and Williams. Many of these species are represented by dozens of well-preserved specimens. These collections have served as a source of comparative material in the study of the McCraney fauna.

Correlation of the McCraney Limestone

The fauna of the McCraney beds was compared with those of the various Kinderhook formations of the Upper Mississippi valley and with those of other terranes whose places in the Mississippian system have been questioned. Only one fauna was found to display any considerable similarity in specific and faunal composition. This is the fauna of the Louisiana limestone of Missouri and Illinois.

A critical review of the McCraney species shows that with

few exceptions they all occur in the Louisiana limestone. *Rhynchopora pustulosa* (White) probably equals *R. rowleyi* Williams and *Syringothyris halli* is near if not actually the same as *Syringothyris hannibalensis* (Swallow). Two notable exceptions are *Linoproductus ovatus* (Hall) and *Chonopectus fischeri* (N. and P.). The latter also occurs in the English River sandstone and in the Maple Mill shale. However, in these formations it has been reported only from Iowa and its absence from the limestone farther south is not remarkable. *Linoproductus ovatus* has been found only in the most northern occurrence of the McCraney limestone in Franklin county, Iowa, and is not present in the Burlington area. Its absence, then, in the southern McCraney outcrops is not surprising.

While the extensive macrofauna of the Louisiana limestone is mostly lacking in the McCraney, the species in common to the two terranes appears to be highly significant. The Louisiana limestone is notably barren in many localities, especially in the Hannibal region where Williams (1943, p. 23) noted his failure to obtain fossils. The major portion of the Louisiana beds is relatively unfossiliferous compared to the basal portion according to Moore (1928, p. 45). Therefore, the sparseness of the fauna of the McCraney, if the two formations are correlatives, may be explained in that it is the upper portion rather than the lower fossiliferous part of the Louisiana that is represented in the McCraney limestone of Iowa and Illinois. Again the McCraney limestone has scarcely been explored for fossils and may be expected to yield additional specimens on further search. On the other hand the macrofauna of the McCraney cannot be said to be as closely related to that of any other formation as it is to that of the Louisiana.

The evidence afforded by microfossils is even more emphatic in support of the correlation of the McCraney with the Louisiana. The occurrence and preservation of the microfossils is the same in the two terranes and appear to add weight to the suggestion that they are one limestone. The fauna in each is secured by collecting the shaly interlayer material from between otherwise barren beds of limestone. All species thus far secured from the McCraney and identified, namely, *Ambocoelia minuta* White, *Ambocoelia louisianaensis* Williams, *Selenella pediculus* Rowley, *Chonetes ornatus* Shumard, *Crania*

dodgei Rowley, *Bembexia minima* Rowley, *Schuchertella louisianaensis* Williams, *Strophalosia beecheri* Rowley and *Mesoblastus* sp. are found elsewhere only in the Louisiana limestone. Perhaps more important is the occurrence in the McCraney of the characteristic microcrinoid, *Hybochilocrinus americanus* (Rowley). The identification was kindly verified by Dr. Marvin Weller. Hitherto it has only been found in a shale parting in the Louisiana limestone at Louisiana, Missouri. The only other species described from North America occurs in the Chouteau limestone of Missouri and differs sufficiently to be readily distinguished from the Louisiana form. Other echinodermal remains are common in the McCraney and resemble some of those seen in the Louisiana. Among them are examples of plates of *Platycrinus* and possibly of *Poteriocrinus*.

STRATIGRAPHIC EVIDENCE

The McCraney limestone was described and named by R. C. Moore (1928, p. 21) from outcrops near Kinderhook, Illinois, the type locality of the Kinderhook series. The name is derived from McCraney creek, a stream a mile or so north of Kinderhook. An extensive disused quarry a mile or so northwest of the road junction displays the Kinderhook beds in a section identical with that noted by Meek and Worthen in 1861 in their description of the Kinderhook. Moore correlated the limestone with a nearly identical formation at Burlington, Iowa.

The McCraney limestone is rather thinly and somewhat irregularly bedded. The major portion of the rock is usually lithographic in texture and light gray. Thin seams of clay or clayey material may occur between the layers. Portions of the rock adjacent to the bedding planes are often irregularly dolomitic and buff as contrasted with the remainder. The irregular distribution of the dolomitic buff portions gives a vertical face of the limestone a typical mottled appearance. In this feature and in its lithology the McCraney differs but little from the Louisiana limestone.

In thickness the McCraney formation varies from a feather edge near New Canton, Illinois, to about ten feet at the Pigeon Creek schoolhouse about eight miles north of Kinderhook and to twenty-five farther north. At the plant of the Marblehead

Limestone Co. the McCraney (Kansas Geol. Soc. Guidebook, 1941, p. 74) is reported to be about forty-seven feet thick. In Iowa it is about six to twelve feet thick in the region of Burlington and is at least ten feet thick in Franklin county.

The McCraney limestone extends northward along the bluffs of the Mississippi from a point a mile north of New Canton, Illinois, until it passes beneath river level about ten miles south of Quincy. It next appears at the surface near Burlington, Iowa, and extends northward along the west wall of the Mississippi valley to the southern part of Louisa county. Thence it occurs intermittently in the south wall of the Iowa river valley to Wellman, Iowa. A considerable gap in the outcrop, generally due to erosion, but partly to burial beneath glacial drift, occurs in the area between Iowa and Franklin counties. A small area in Geneva township and an outlier north of Maynes Creek in Franklin county are the northernmost surface occurrences of the McCraney limestone.

The McCraney seems to have been considered a distinct terrane by Moore chiefly because at Kinderhook, Illinois, it overlies a massive siltstone. This he correlated with the Hannibal formation in its more southerly exposures in the east wall of the Mississippi valley. If this correlation is correct, then the lithographic limestone, McCraney, could not be the same as the lithographic limestone, the Louisiana, lying below the Hannibal at Hannibal and Louisiana, Missouri. However, the writer does not regard as established beyond doubt the equivalency of the siltstone below the McCraney with the Hannibal above the Louisiana.

The stratigraphy of the beds involved may be profitably reviewed by first noting the strata in the Burlington region of Iowa. The well-known and much-studied Prospect Hill section of Iowa is as follows:

8.	Burlington limestone	25 ft.
7.	Wassonville limestone	5
6.	Oolite	3–4
5.	Prospect Hill siltstone	5
4.	McCraney limestone	10
3.	Oolite and shell limestone	1
2.	English River siltstone	18
1.	Maple Mill shale	25+

There is no doubt about the designation of the beds below the McCraney limestone as they can be traced into the type

sections of these formations on the English River in Washington county, Iowa. The strata of this section dip below river level south of Burlington and next appear in the east wall of the Mississippi valley below Quincy, Illinois.

The Mississippian section near Kinderhook, Illinois is approximately:

4.	Burlington limestone	25+ ft.
3.	McCraney limestone	10
2.	English River siltstone	30
1.	Maple Mill shale	40+

There seems to be general agreement among geologists regarding the designation of the beds below the McCraney (Kansas Geol. Soc. Guidebook, 1941, p. 72). Weller (1905, p. 623) has found in the siltstone a fauna which he definitely states is English River. Several terranes between the Burlington and McCraney limestone are absent in the immediate vicinity of Kinderhook. However, a few miles to the northward a siltstone comes in between them and there appears little doubt that it is the southern extension of the Prospect Hill siltstone of Iowa. It also differs but little from the upper part of the Hannibal as seen in the western part of Hannibal, Missouri (Kansas Geol. Soc. Guidebook, 1941, p. 66).

At Hannibal, Missouri, about 16 miles west of Kinderhook, is a well-known section:

3.	Burlington limestone	100 ft.
2.	Hannibal shale and siltstone	70 ft.
1.	Louisiana limestone	30 ft.

In the region of Hannibal a considerable thickness of shale is seen (Williams, 1943, p. 24; Grohskopf, Hinchey and Greene, p. 15) below the Louisiana in several places.

The next important section is at Hamburg, Illinois, along the creek in the south part of town.

7.	Burlington limestone	
6.	Shale and sandy shale (Hannibal)	75 ft.
5.	Glen Park sandy dolomite and oolite	12
4.	Louisiana limestone	5
3.	Shale (Saverton)	1
2.	Cedar Valley limestone	5
1.	Silurian	20

Bed 3 is a dark shale and is thought by some geologists to be Saverton. Bed 6 apparently is Hannibal and is the terrane which Moore states can be traced into the English River

siltstone of the Kinderhook section. If true then the McCraney limestone must be younger and a separate designation would be warranted.

Since the Kinderhook beds concerned are exposed almost continuously in the east valley wall of the Mississippi and in tributary valleys from Kinderhook to Hamburg, an examination was made at a number of places which seemed to be critical in working out the stratigraphic relationships of the beds or where the rocks were best exposed and more accessible. Several observations were made of sections which appear to cast doubt on the correlation of the Hannibal and English River siltstones.

In the south bank of the first creek (Wild Cat Hollow) north of Belleview, Illinois, about a half mile east of the highway is an important section.

2. Louisiana limestone, lithographic with dolomite partings ..... 30 ft.+
1. Siltstone, bluish, massively bedded, base not exposed, English River ..... 6 ft.+

Louisiana limestone with typical fossils occurs at Hamburg about eleven miles south, and Belleview is across the river and southeast of the type locality of the Louisiana limestone at Louisiana, Missouri. Moore states (1928, p. 45) that the Louisiana limestone is present in Calhoun county, Illinois, and Williams (1943, p. 9) maps it as present in the county to the north as well. Consequently it appears certain that the upper terrane of the section is Louisiana limestone. The siltstone at the base is strikingly similar to the English River beds and the section duplicates some seen near Burlington, Iowa. If the siltstone is not the English River it is an hitherto undescribed terrane.

In the hill on the north side of the same valley and adjacent to the highway is another and more extended section.

3. Limestone, Louisiana ..... 3–4 ft.
2. Siltstone, English River ..... 4–5 ft.
1. Shale, Maple Mill, mostly covered .. . 15 ft.

The section is continued about 100 yards farther north on the same hill.

5. Burlington limestone ..... 30 ft.+
4. Shale, Hannibal ..... 70 ft.+
3. Limestone, Louisana .....15–20 ft.

The same section was also observed at a place a mile south

of the county line. It will be noted that the Hannibal beds of the Hamburg section occur here in full force above the Louisiana limestone. Consequently the siltstone below, which the writer believes to be English River, appears to be a distinct terrane. Although the Glen Park beds are not seen in these sections, they are commonly present in a number of places as far north as Rockport.

Along the second creek north of Atlas (Jim Town Branch) about a half mile east of the highway is a good section showing the relationship of the Glen Park to the beds above.

4.	Siltstone, Hannibal, blue, massively bedded, grading into bed below; higher beds upstream more shaly	5–6 ft.+
3.	Shale, Hannibal, blue, elsewhere brown or intermottled with blue	4 ft.
2.	Dolomite, Glen Park, buff, upper surface irregular	1–2 ft.
1.	Limestone, Glen Park, oolitic; conglomeratic, pebbles of lithographic limestone, well rounded; dipping downstream; massively bedded above, weathering into thin plates below	5–6 ft.

Some distance downstream is a shale, apparently Maple Mill, as both English River and Louisiana formations have feathered out some miles to the southward.

At Rockport, Illinois, in an extensive ravine in the south part of town the same beds are again seen.

3.	Shale and siltstone, Hannibal, blue	10 ft.+
2.	Dolomite, Glen Park, blue when unweathered, buff, massively bedded, fossiliferous, sharp contact with shale below	6 ft.+ –
1.	Shale, Maple Mill, considerable thickness, has two thin widely-separated layers of limestone	30 ft.+

In the north part of Rockport in a ravine a block north of the church is another section as follows, (thickness estimated):

6.	Burlington limestone	6 ft.+
5.	Siltstone, massive, wormlike markings 2–3 feet of shale at top, Hannibal?	20 ft.
4.	Siltstone and shale, mostly covered	15 ft.
3.	Shale, blue, mostly covered	10 ft.
2.	Siltstone, massively bedded, resistant, fossiliferous, forming a declivity, English River?	15 ft.
1.	Covered interval above road	30 ft.+

A block of Glen Park oolite, not in place, indicates that it is present as well. The possibility exists that more than one siltstone is present here, but this can only be assured when the position of the Glen Park is known definitely.

The McCraney limestone north of Kinderhook has siltstone above and English River siltstone and Maple Mill shale below. The same stratigraphic positions of these beds are seen in the case of the Louisiana at Belleview. Since the lithology of the Louisiana and the McCraney is identical (Weller 1905, p. 624) and the fauna apparently the same, it seems probable that the two terranes are members of the same limestone body. In support of this is the observation of Weller and Sutton (1940, p. 785) that the two limestones have never been seen in the same section. S. E. Harris, Jr. (1947) has recently studied samples of wells from northeast Missouri and southern Iowa and has apparently traced the Louisiana limestone into

<table>
<tr><th>Moore** 1935</th><th>Standard Section</th><th>Present Paper</th></tr>
<tr><td>Burlington</td><td>Burlington</td><td>Burlington</td></tr>
<tr><td>Wassonville</td><td>Sedalia</td><td>Wassonville</td></tr>
<tr><td>____ Oolite</td><td rowspan="3">Chouteau</td><td rowspan="2"></td></tr>
<tr><td>Prospect Hill</td><td>____ Oolite</td></tr>
<tr><td>Mc Craney</td><td rowspan="2"></td></tr>
<tr><td>English River</td><td rowspan="2">Hannibal</td><td>Prospect Hill</td></tr>
<tr><td rowspan="3">Maple Mill</td><td rowspan="2"></td></tr>
<tr><td>Glen Park</td><td>Mc Craney</td></tr>
<tr><td></td><td>Louisiana</td><td>English River</td></tr>
<tr><td></td><td rowspan="2">Saverton</td><td>Maple Mill</td></tr>
</table>

Figure—1 Correlation of Lower Mississippian of southeastern Iowa and northwestern Illinois discussed in this paper.

** Moore, R.C., 1935, Ninth Annual Field Conference, Kansas Geological Society, page 245.

the McCraney. He has recognized the McCraney in Iowa as Louisiana. The isopach map of the Louisiana limestone by Williams (1943, p. 9) also favors this interpretation of the relationship between the Louisiana and the McCraney.

The Glen Park sandy dolomite and oolite can be traced almost continuously northward from Hamburg to Rockport. It lies on Louisiana at first, then on Maple Mill as the English River and Louisiana beds were eroded or were never deposited in the region between Rockport and north of Belleview. The Glen Park is seen at several places in Rockport but appears to end abruptly there, as it is not seen in section beyond to New Canton.

The stratigraphy of the lower Mississippian formations in the east wall of the Mississippi valley may be summarized from the sections given above and from outcrops not mentioned (fig. 1).

The Maple Mill shale of the Kinderhook section appears to be traceable almost continuously along the Mississippi bluffs into the Saverton shale at Hamburg. From a thickness of one foot at the latter place it increases in thickness to the northward, becomes less fissile, less black, more grayish and merges with the typical Maple Mill shale. As the base was not observed in most places, the thickness is unknown except at Hamburg. In no place did the writer observe this basal Kinderhook shale to unite with the Hannibal beds.

The English River siltstone rises gradually to the southward from Kinderhook and comes to underlie the Burlington limestone as the McCraney feathers out just north of New Canton. It may continue southward nearly as far as Rockport but at that place and beyond it has been removed so that Glen Park lies on Maple Mill. The English River siltstone is apparently absent for a considerable distance and next reappears a mile or so north of Belleview. In the south side of the valley of the first creek north of that place, it occurs immediately below Louisiana limestone, has its typical lithology, and is six feet thick with the base not exposed. This section is similar to some in the Kinderhook area of Illinois. The fact that both English River and Hannibal may be seen in the same section north of Belleview would seem to show that they are not correlatives. The siltstone disappears north of Ham-

burg as the shale beneath simultaneously thins to a thickness of one foot.

The thick body of shale above the Glen Park beds at Hamburg, apparently Hannibal, becomes more silty so that at Rockport it is a thick body of siltstone lying on Glen Park. It may continue northward and overlap on English River. It would be difficult to distinguish them in the same section because of their lithologic similarity without Glen Park or Louisiana between. On the other hand the Hannibal may disappear to the northward of Rockport either through erosion or nondeposition. The abrupt disappearance of the Glen Park just north of Rockport lends credence to the possibility that the Hannibal does likewise. The writer was not able to trace the beds from Rockport to New Canton but does not believe that the Hannibal can be traced into the English River. The two terranes may occur, one above the other north of Rockport and would be hard to separate because of their lithologic similarity without the presence of formations which elsewhere occur between them. The possibility of confusion and variable interpretations of the beds north of Rockport is evident. On the other hand Harris (1947) states that there is subsurface information at hand that the Prospect Hill of Iowa thickens to the south and southeastward of Burlington until it merges with the Hannibal of Missouri. The siltstone above the McCraney north of Kinderhook, Illinois, would appear to be Hannibal.

The Burlington limestone can be traced continuously from Kinderhook to Hamburg, Illinois, as in the case of the Maple Mill. This is true also in Iowa where the Burlington and Maple Mill are continuous over large areas and enclose between them a number of discontinuous formations as the English River, Louisiana, Prospect Hill and others.

CONCLUSIONS

1. The lithologic and faunal similarity and apparently identical stratigraphic position of the McCraney and the Louisiana strata lead to the conclusion that they are portions of the same body of limestone. This substantiated by tracing the Louisiana in subsurface in northern Missouri into the McCraney in Iowa (Harris, 1947).

2. The extent of the Louisiana limestone is thus much greater

than hitherto recognized, as its outcrops range from Franklin county, Iowa to Hardin county, Illinois.

3. The McCraney limestone is not a member of the Hannibal formation. Since the name Louisiana has precedence, the term McCraney may well be dropped.

If it is granted that the McCraney and Louisiana limestones are parts of the same formation it follows that the siltstones which lie above and below are different formations.

4. The English River siltstone is not a member of the Hannibal formation. This is favored by the difference in the faunas of the two terranes as appears in a study of Moore's lists (1928, p. 53). An inspection of the table of Hannibal species collected at Louisiana, Missouri, (disregarding the columns of collections at Rockport and Pleasant Hill which are Glen Park) shows that only five occur in the English River siltstone. This proportion is not large considering their similar lithology which is indicative of the same ecological environment. Also, fossils of these siltstones being molds exclusively are sometimes difficult to identify accurately. Finer differences are often obscured or lost. Faunally the English River is more definitely related to the Louisiana and Maple Mill in Iowa (Weller 1905, pp. 624-5).

5. The Hannibal formation is represented in Iowa and in the Kinderhook region of Illinois by the Prospect Hill siltstone. The macrofauna of the Prospect Hill is quite similar to that of the Hannibal as Moore states (1928, p. 21). This correlation is further strengthened by a study of Prospect Hill conodonts by Youngquist and Patterson who found them to be similar to those of the Hannibal. Furthermore the Prospect Hill has many species in common with the Northview sandstone of southwestern Missouri. That formation is said by Weller (1905, p. 633) to be equal to the Hannibal. Likewise the Prospect Hill may be traced below the surface into Hannibal beds (Harris, 1947).

6. The Maple Mill shale is apparently traceable in Illinois from Kinderhook south into the Saverton shale at Hamburg. They appear to be parts of the same body of shale. If so, Maple Mill has precedence by twenty-five years. The fauna of the Saverton in Missouri is related to the fauna of the Louisiana and the same is true of the fauna of the McCraney and the Maple Mill. The latter is not a member of the Han-

nibal formation as is shown by its fauna and stratigraphic position.

7. An early Mississippian age for the Louisiana limestone is indicated by its fauna and its stratigraphic situation above English River siltstone and Maple Mill shale, recognized by geologists generally as basal terranes of that system. Williams has recently considered at length the evidences for the assignment of the Louisiana to the Mississippian and his arguments need not be repeated here. A few comments on the fauna, inclusive of that of the McCraney, may be added. The Louisiana fauna as a whole has few of the aspects of any Devonian fauna known to the writer. None of the larger invertebrate species occurs in any known Devonian formation. Few, if any, of the distinctive genera of macrofossils of the Upper Devonian of the Mississippi valley are found in the Louisiana.

On the other hand Williams found that a number of Louisiana species do occur in recognized Mississippian formations. Five are present in the Prospect Hill siltstone at Burlington, four in the English River siltstone, four in the Glen Park beds, five in the Chouteau limestone, nine in the Waverly beds of Ohio and five in the Hannibal beds. It is true that many of the characteristic productids of the Mississippian are absent in the Louisiana. However, *Avonia*, represented by *Avonia pyxidata* (Hall) is present therein. It is not a true *Productella* as it lacks the high cardinal areas of that Devonian genus and has in addition radial plications on the front of the valve of many specimens. Others are quite smooth but this is readily explained by assuming that the developing genus had not yet attained its mature characteristics so early in the Mississippian. The presence of *Linoproductus ovatus* (Hall), a species with an extended range in the Mississippian and occurring in the northernmost exposures of the Louisiana limestone in Iowa, is highly indicative of the post-Devonian age of the terrane. The presence of *Chonopectus*, *Torynifer* and *Paraphorhynchus* is further support for this assignment.

The Maple Mill shale and the English River siltstone below the Louisiana limestone in Iowa include such genera of productids as *Linoproductus*, *Dictyoclostus* and *Krotovia*. In Franklin county, Iowa, the Louisiana overlies the Chapin bed which has an extensive Mississippian fauna as listed by Laudon (1931, p. 393, *Cyathaxonia* zone). If the McCraney and

Louisiana beds are the same, it appears nearly conclusive that the latter is Mississippian.

Branson and Mehl have placed the Louisiana limestone in the Upper Devonian. Apparently this placement is based on evidence afforded chiefly by conodonts and by its stratigraphic relationships with the Grassy Creek shale. The writer believes that the usefulness of conodonts as stratigraphic markers has as yet not been completely determined. Likewise it is uncertain how much weight should be attached to them as evidence of geologic age, especially if conflicting with that given by other groups of fossils.

Branson and Mehl (1939) list five genera of conodonts as diagnostic of Devonian age. One, *Icriodus*, occurs in the Louisiana limestone with a macrofauna which Williams regards as Mississippian. In this opinion the writer is in full agreement since, as shown, above, the affinities of the Louisiana larger fossils are with those of the McCraney which are definitely Mississippian. The characteristic and unique microcrinoid, *Hybochilocrinus americanus* (Rowley), occurs in both terranes. Is not the evidence of age given by this crinoid as good as that of *Icriodus*?

Similarly L. A. Thomas lists the five conodont genera as present in the Maple Mill shale of Iowa and accordingly places the formation in the Devonian. The macrofauna, however, is plainly related to the Mississippian rather than to Devonian faunas. For instance the brachiopod *Chonopectus* occurs in the Maple Mill, in the English River and in the Louisiana (McCraney) of Iowa. Caster also lists it in the fauna of the Mississippian Corry sandstone of northeastern Pennsylvania. Moreover, besides faunal relationships the contact between the Maple Mill and the English River siltstone is a gradational one and does not appear to the writer to be intersystemic.

The Upper Devonian limit of the geologic ranges of these genera of conodonts does not seem to be established beyond reasonable doubt. The genera, *Ancyrodella*, *Polylophodonta* and *Palmatolepis* are said by Branson and Mehl (1933) to be present in the Bushberg of Missouri but are thought by them to be contaminants. *Ancyrognathus* is listed by Branson (1938, p. 334) in the Hannibal shale. *Palmatolepis* and *Icriodus* are said by C. L. Cooper to be present in the Upper New Albany

beds, generally regarded as Mississippian. This author has recently discussed these genera (1948, p. 103) and casts some doubt on their importance as decisive Devonian markers. Others may yet be found to occur in formations higher than Devonian as some Mississippian formations have as yet been incompletely explored for conodonts.

8. The Kinderhook succession in the Upper Mississippi valley seems to be as follows: 1. Maple Mill shale, 2. English River siltstone, 3. Louisiana limestone, 4. Hannibal shale and siltstone, 5. Chouteau limestone.

ACKNOWLEDGMENTS

The writer wishes to thank Dr. H. G. Hershey, Director of the Iowa Geological Survey, for permission to use information gained while a member of the organization. He also benefited much from discussions of the problem with Dr. Hershey and other members of the survey. However, the writer assumes full responsibility for the conclusions expressed in this paper.

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Brandon, Iowa

LONG LOST METEORIC STONES RECOVERED

STUART H. PERRY

THE recovery, after almost a century, of the two masses of the Girgenti meteorite, a white veined chondrite, makes a story of rather unusual interest to students and collectors in that line. Hitherto only fragments were known, aggregating 3,389 grams, but within the last year the writer has acquired the two stones vaguely mentioned by older writers—one of 8,750 grams and one of 2,151 grams.

Both specimens are in perfect preservation, showing well both the original fusion crust and the characteristic veined structure on broken surfaces. The smaller one is about half of its original size, the missing portion having furnished most of the fragments distributed sixty or seventy years ago to various collections.

The fall, which occurred in Sicily on February 10, 1853, near Girgenti (now Agrigento) was first mentioned by Greg in 1854 as "a large stone." A full petrographic description was published by Vom Rath in 1869, giving all the information then available on the history of the fall. The fragments then known, two of which he studied, aggregated less than 100 grams.

Wülfing in his exhaustive and meticulous listing (Die Meteoriten In Sammlungen, 1897) gave the total of all fragments of Girgenti as 3,389 grams. Though almost thirty years had elapsed since Vom Rath's paper, he knew nothing definite about the two main masses. He says: "Ursprüngliche Gewicht: mindestens 2 Steine. Greg sagt 'a large stone.' Buchner sagt 'der Stein wog 3-4 kg.' Nachweisbares Gewicht 3,389 gr."

The description of Girgenti by Vom Rath (Poggendorff's Annalen 138, pp. 541-545, 1869) is in part as follows:

"The stone that fell February 10, 1853, near Girgenti, Sicily, belongs among those meteorites that are little known, and only through samples in a few small collections. According to Professor Buchner the stone weighed 3 to 4 kg. Fragments of it are in the possession of Greg (9.2 gr), in Vienna (17.5 gr), London (7.02 gr), as well as in the Reichenbach collection, and finally those of Shepard and Nevill; while the prin-

cipal mass has remained in the possession of Prof. Gemmellaro, now in Palermo. Regarding the stone itself Buchner says it is 'dense, fine-grained, and includes fine silver-white iron particles.'

"Since Dr. Krantz has not only placed at my disposal for study the two larger pieces of stone lately brought from Palermo (16.602 gr and 38.439 gr in weight), but also gave me several smaller fragments for analysis, I very gratefully avail myself of the opportunity to contribute something to the knowledge of that rare stone.

"Unfortunately my wish to learn something of the circumstances of the fall was not fulfilled. Mr. Gemmellaro at my request interviewed several persons in Girgenti, but no one could be found who was an eye-witness of the occurrence, or who could give any reliable information about it. It is one of the many meteoric falls of which the phenomena are wholly lost to science.

"The supposition that only one stone fell at Girgenti seems to be erroneous according to the statement of Gemmellaro in a letter, who mentions in addition to the one in his possession still another 'whole stone' (pietra entera) belonging to the same fall. Gemmellaro's stone is, except for the pieces broken off, fully crusted. The two pieces submitted to me are partly covered with a black fusion crust. It is somewhat wavy and shows small prominences which betray the presence of nickel-iron. The stone is a chondrite, light grayish-white, very fine-grained, appearing almost homogeneous to the eye.

"On a broken surface appear a multitude of very fine fusion lines. They run from the outer fusion crust, and appear to have been filled from it; although it is inconceivable in view of their exceeding smallness, at times only observable with a loupe, that they could have been filled from the molten matter.

"The fine black fusion lines, forming a confused network, run through the recognizable components in the midst of the mass; that is to say, the condrules and the rounded crystalline grains of olivine. The fusion lines mostly bend around the particles of pyrrhotite, though at times I noticed that the particles were traversed by the lines.

"The nickel-iron scattered through the silicate groundmass is silver-white in color. Most of the particles are smaller than in, for example, the Pultusk stone. Pyrrhotite appears rather

more abundantly than the iron; it is bronze-yellow to tomback brown in color, occasionally running into steel blue."

A further discussion of the components is followed by analyses showing 8.3% of nickel iron in the mass, the composition of which is given as 87.3 Fe and 12.7 Ni, and by analyses of the non-metallic portion.

The uncertainty regarding the "two stones" now apparently is cleared up. In 1948 through correspondence with Giuseppe Bonafede of Palermo, a collector of minerals and fossils, the writer learned that he had the two masses and obtained them from him, together with their history.

The fall, according to Mr. Bonafede, was on a farm near Girgenti then owned by Gaspare Lo Giudice. It took place during a storm, accompanied by a flash of light and the characteristic noise, alarming the farm workmen. Several of them found a heavy stone that had fallen and brought it to Mr. Lo Giudice, who gave it to his friend Salvatore Bonafede of Palermo, an amateur student of rocks and minerals and an uncle of Giuseppe Bonafede.

Subsequently Lo Giudice gave him a second stone, presumably one that he had kept from the time of the fall. Giuseppe Bonafede inherited both in 1909 when the uncle died at the age of 70 years.

Which of these stones was the one of 3 to 4 kg. mentioned by Buchner, and which was the "pietra entera" referred to indefinitely by Gemmellaro in his letter to Vom Rath?

Mr. Bonafede states that when his uncle first received a stone from Lo Giudice he lent it to Prof. Gemmellaro for study. The latter, whose full name was Gaetano Giorgio Gemmellaro, was a professor of Geology in the University of Palermo, where a street still bears his name. He was a close friend of Salvatore Bonafede, but did not know Lo Giudice.

The fact that he borrowed the stone for study would indicate that it was a new meteorite, the first recovered. That also may be inferred from the fact that Salvatore Bonafede broke off and sold fragments of it after Gemmellaro had returned it to him. Though Gemmellaro in his letter to Vom

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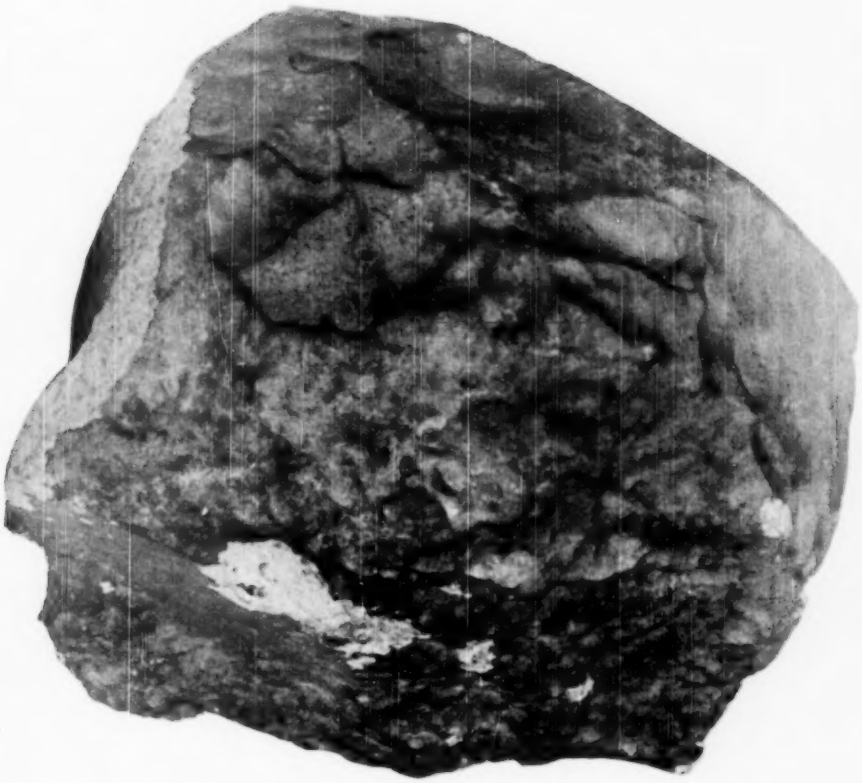
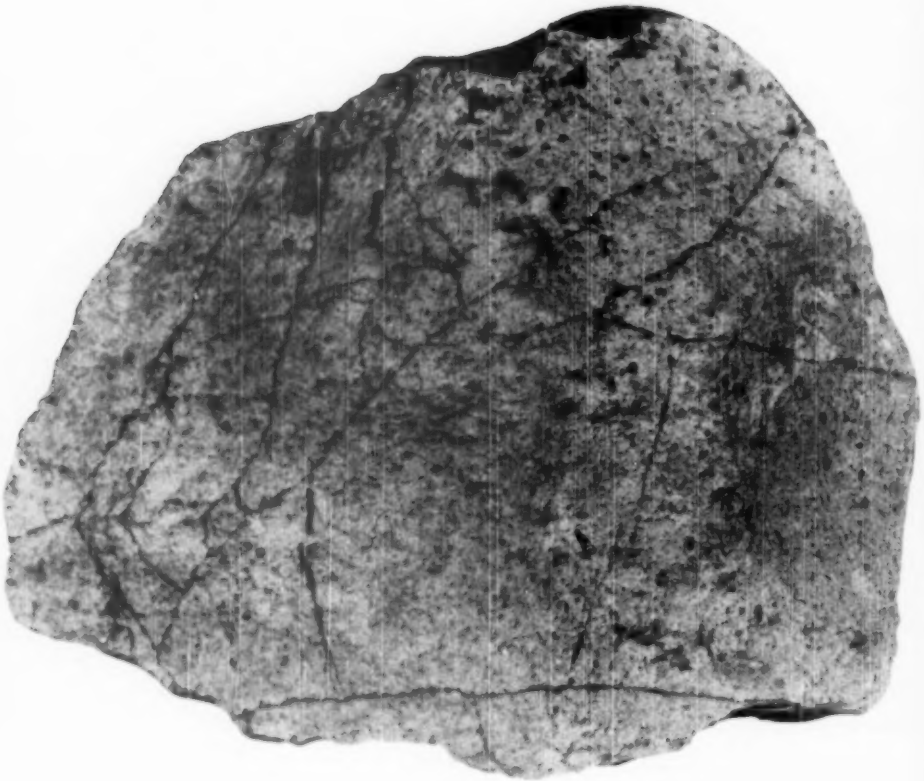
PLATE 1

The smaller (2,151 gr) Girgenti stone shewing fusion crust. (The photo is slightly larger than natural size, which is 13 cm. in length.)





Rath mentioned the existence of a second stone—the "pietra entera"—its location was apparently unknown at that time. It could not have been in the possession of Salvatore Bonafede, so evidently Lo Giudice gave it to him subsequently. This must have been considerably later, because in his letter at least fifteen years after the fall Gemmellaro had no definite knowledge of the second stone. This stone, we may conclude, is the "pietra entera," which until now remained unknown to scientific writers.

The smaller stone seems to be about half of its original mass, and the portions broken away probably account for most of the fragments listed by Wülfing. It seemed a natural supposition that the fragments were broken off by Gemmellaro, but Mr. Bonafede states that they were broken off and distributed by his uncle, the professor having had the stone merely as a loan. He states that the original weight (as recalled by his uncle) was about 4 kg. If so, some of the 3,389 grams listed by Wülfing must have come from other sources, perhaps fragments found on the Lo Giudice farm.

Of the 3,389 grams in Wülfing's list 2,792 were in six collections—Rome 1,104, Berlin 489, Paris 474, Turin 184, London 246, Pohl 208. The remaining 597 grams of fragments, from 87 grams down to one, were scattered in 22 collections—all European except Harvard 20 grams, Bement 1, and Washington 1. As late as 1912 Foote in his list of meteorite values considered Girgenti such a rarity that he gave it a value of $2.07 a gram.

The distribution as given by Wülfing probably has not materially changed, though London now has 120 grams more, Paris 107 less, and available catalogues give Chicago 85 grams, New York 8.9, Prague 14 and Greifswald 4. There likely has been some redistribution of the 263 grams in private collections included in Wülfing's total.

After acquiring the two main masses, the writer obtained 185 grams of fragments—seven weighing 93 grams from Mr. Bonafede who got them from Giuseppe Lajacarno of Agrigento, and 92 grams from the collection of Professor Meli of Rome.

PLATE 2

Broken surface of the smaller Girgenti stone showing veins. (The photo is larger than natural size, which is 11 cm. wide and 10 cm. high.)

Thus the weight of all known fragments is increased to 3,574, which added to the 10,901 grams of the two masses, gives 14,475 grams as the total known weight.

Girgenti is a typical white veined chondrite, the accompanying illustrations showing the characteristic veining and fusion crust. The photographs were taken of the smaller mass because it shows the veining more distinctly than the broken surface of the larger one.

The large stone is somewhat quadrangular. It is about 25 cm. long, 15 cm. high and 15 cm. thick, treating the flattest side (about 23 x 13 cm.) as the base of the mass. This base is crusted, and there are remnants of crust on the top.

The crusted surface of the base is quite flat and even, the depressions being too small and numerous to be properly described as thumb marks. One side, about 20 x 10 cm., bears a well-preserved crusted area about 5 x 10 cm. which shows characteristic thumb marks, and the same is true of remnants of the crust on the top, and of an area about 7 x 12 cm. on one end of the mass.

One side presents a fairly even broken surface about 23 x 12 cm., which is slightly darkened to a general brownish shade. This darkening does not suggest an incipient crusting or "scorching" during flight; it is likely that in the course of almost a century oxidation has made brownish spots around the minute and thickly dispersed grains of nickel-iron.

The top presents a broken surface about 18 x 7 cm. which appears fresher than the one just referred to, it being light gray with no spots of oxide. This surface shows distinctly the veins, a number of which are traceable for 18 or 20 cm. across the top and down the broken side.

The smaller mass is very similar to the larger. It has rounded outlines, though somewhat quadrangular in its general shape. It is about 13 cm. long, 11 cm. wide and 10 cm. high, considering the flattest side as the base of the mass. The base, one side and the top are covered with a perfect and fresh-looking crust. The side and top are strongly thumb-marked; the basal surface, which is quite even, shows only small depressions.

One side and both ends show fresh-looking broken surfaces on which the numerous veins are conspicuous. From the general shape and curvature, the mass may be approximately

half of its original size. This is consistent with the statement of Mr. Bonafede that the stone originally weighed about 4 kg., and with the statement of Buchner that there was a stone of 3 to 4 kg.

The larger stone has been given by the writer to the United States National Museum, the smaller to the Chicago Natural Museum.

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REVIEWS

Fluid Dynamics; by VICTOR L. STREETER. Pp. xi, 263, New York, 1948 (McGraw-Hill Book Co., Inc., $5.00).—This is a textbook for use in a senior or graduate course in fluid mechanics. The material is well arranged, and great care has been taken to present all mathematical detail needed for an understanding of this very analytic subject. Proofs tend to be lengthy and little is left to the reader, all of which gives the book a wholesome measure of teachability and places its contents well within the grasp of a student who has had a course in the calculus. An awkward prose, a profusion of dangling participles make the text material at times a bit obscure, but equations and diagrams always shed sufficient illumination to sustain the reader.

The plan of the book is well described by the publisher, who notes on its fly leaf:

"This book first formulates the basic ideal fluid theory, followed by examples of three-dimensional flow. Then, the necessary concepts in complex variables are introduced, so that all two-dimensional flow cases may be approached from the viewpoint of conformal mapping. Free streamlines are introduced with several examples of their use. Vortex theory is then developed, with two- and three-dimensional examples. The Navier-Stokes equations are derived and applied to several flow problems, including the laminar boundary layer."

HENRY MARGENAU

Irrigated Soils; Their Fertility and Management; by D. W. THORNE and H. B. PETERSON. Pp. ix, 288; 74 figs. Philadelphia and Toronto, 1949 (The Blakiston Company, $5.00).—This new book on the management of irrigated soils should be useful to everyone interested in water movements in the soil profile and their relation to crop production, engineering, geology, and the like. It is the only one of its kind available, as most books on soils deal with their use and management for crop production in humid areas. The management of soils in arid regions is given special emphasis.

New concepts of soil moisture are presented clearly and are illustrated unusually well with diagrams. The book also discusses relationships between organic matter, microbiology, fertilizers, and their use as ordinarily covered in general texts on soils. Other chapters of special interest, out of the 25 included in the book, are Soil, Water, and Plant Relations; Plant Relations to Saline and Alkali Soils; Evaluating Land for Irrigation; Measuring Irrigation Water; Field Application of Water; Irrigation Practices for Various Crops;

Effects of Irrigation on Soil Characteristics; Drainage; Reclamation and Management of Saline and Alkali Soils; and Control of the Physical Properties of Soil.

Particularly helpful to those not specially familiar with soil terminology is the inclusion of a Glossary. Some of the terms used are new and have not yet been established in the literature. It may be premature to include them for their definition may change with usage. An Appendix is also included giving information useful in soils work.

A Bibliography is included at the end of each chapter. Reference is not made to all of the references in the text which tends to lessen the usefulness of the Bibliography.

The book could have been improved by including a chapter on the basic nature of soils, as, for example, description of a soil profile. It would also have been helpful to have included morphological descriptions of soil structure in arid regions in more detail since the natural structure of soils in those regions exert such a profound influence on their use.

The book is well printed and well illustrated; especially good are the diagrams and graphs showing moisture relationships in soils.

C. L. W. SWANSON

Structural History of the East Indies; by J. H. F. Umbrove. Pp. xii, 64 (quarto); pls. 10, figs. 68. London and New York, 1949 (Cambridge University Press, $4.00).—This is a refreshing book. Based on a series of lectures given at Cambridge in 1946, it is informal in tone and disarmingly undogmatic in argument. It ends with a statement of the vastness of our ignorance and a frank admission that the working hypothesis so lovingly erected is certain "to be discarded as soon as new facts are revealed." Yet there is a dramatic quality in its plan, which begins with a quiet discussion of drowned rivers and coral reefs, builds up subject after subject to the brink of an explanation, and finally ties all threads together in the final chapter.

To be sure, the book does not contain much that is not already in the literature and will not become an indispensible reference work for future investigators. The factual documentation and the chains of argument are too incomplete for that and the bibliography also is short and weighted somewhat in favor of review articles. But exhaustive discussion was not its intent, and the book does present a stimulating review of all the different lines of evidence that must go into a reconstruction of the tectonic history of the East Indies—the configuration of the sea floor and the dis-

tribution of the sediments now accumulating on it, the volcanic activity so prominent in the area, the stratigraphic and structural history revealed by the rocks, and the seismic and gravimetric data available—and proceeds to a carefully considered and attractive synthesis. Moreover it is beautifully prepared and well and lavishly illustrated, though readers would be well advised to provide themselves beforehand with a fairly detailed map of the archipelago.

In short, the book might be considered the geological equivalent of "light" reading, and it provides a brief but unhurried survey of an area of great interest by a master in its geology. From his own experience, the reviewer believes that few geologists will want to put the book down before they have finished the last paragraph. JOHN RODGERS

Pre-Chattanooga Stratigraphy in Central Tennessee; by CHARLES W. WILSON, JR. Tennessee Division of Geology Bulletin 56. Pp. xviii, 408; 28 pls., 89 figs. Nashville, 1949.—Wilson's report is an exhaustive account of the physical stratigraphy of the Ordovician, Silurian, and Lower and Middle Devonian rocks exposed on the Nashville dome and in the Western Valley of the Tennessee River. It is based on mapping of the formations in question and on the measurement of approximately 700 stratigraphic sections. The maps are not included in the report, but they will be released separately by the Tennessee Division of Geology (scale: 2 miles to the inch). Thirty cross-sections, built up of 5 to 21 individual sections each, present the stratigraphic details, which are generalized in several stratigraphic diagrams and 33 isopach maps of various formations and members. There emerges a clear and authoritative picture of the geological history recorded in the rocks. In particular, Wilson's precise data clarify the history of the Nashville dome as a positive area, and he shows how as an island or shoal it influenced the distribution of facies at several times, beginning in the Middle Ordovician.

As a definitive work on the area, the report inevitably invites comparison with the earlier report by Bassler (1932). The differences in interpretation between the two reports are great, and they stem largely from fundamental difference in the approach to correlation. Bassler adhered to the view of E. O. Ulrich that two bodies of rock having different lithology and different fossils are the deposits of separate embayments of the sea and are therefore distinct formations of different ages. Wilson is steeped in modern ideas of facies change, and he recognizes as many as six different roughly contemporaneous facies in certain formations. The change illus-

trates how far American stratigraphy has come in the last two decades.

Two unfortunate defects mar the work. Firstly, the same geographic name is used in a few cases both for a formation and for a member of that formation, in violation of the accepted rules of American stratigraphic nomenclature (Committee on Stratigraphic Nomenclature, 1933, Art. 7, remark f; Art. 11, remark c). These duplications could easily be avoided by using lithologic instead of geographic terms for the members in question. Secondly, throughout the work the names of fossils are given without the name of the original describer. In general it is unfortunate that Wilson, who quite properly checked every aspect of the physical stratigraphy in the field, has accepted much of the paleontology at second hand.

The outstanding contribution made by this report is therefore in physical stratigraphy, particularly in the recognition of the complex facies relationships in the upper Middle Ordovician Nashville group ("Trenton" of previous reports). Inasmuch as these rocks are relatively fossiliferous, the way is now open for some fascinating studies on the control of fossil faunas by depositional environment.

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ERRATA

In the article by F. Chayes "On a Distinction Between Late-Magmatic and Post-Magmatic Replacement Reactions," printed in the January issue, page 27, equation (4) should read

$$r_{13} = \frac{s_1 + r_{12}s_2}{\sqrt{(s_1^2 + s_2^2 + 2r_{12}s_1s_2)}}$$

and page 29, equation in the middle of the page should read

$$r_{13} = \frac{s_1}{\sqrt{(s_1^2 + s_2^2)}}$$

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